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**Educational Psychology Monographs**

This volume, which is No. 23 in the Series,  
was prepared under direction of the faculty  
of New York University.

**PERIODIC VARIATIONS IN EFFICIENCY**



# PERIODIC VARIATIONS IN EFFICIENCY

As shown in Mental and Physical Tests together  
with some Weather Effects

By

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BALTIMORE  
WARWICK & YORK, Inc.

1921

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SEP 24 '21

## PREFACE

Many studies have appeared which suggest the existence of periodic variations in both physical and mental activities during the year, during the day, and in conjunction with periodic changes in natural phenomena such as sunlight and temperature, but as yet the factors involved are but little understood. In order to assist in the solution of these complex problems, the author has attempted the following:

- (1) To give a complete historical view of the experimental data on the subject.
- (2) To examine the means, methods, and procedure employed by other investigators.
- (3) To give a critical evaluation of the results of previous investigations in the light of the means employed, the methods used, and the procedure followed.
- (4) To use improved methods and procedure in investigating the problems of periodicity.
- (5) To summarize the results of previous investigators, and compare them with his own.
- (6) To point out some problems which future investigators should attempt, and some errors which they should avoid.

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## CHAPTER I. GROWTH RHYTHMS

All human life is a growth involving numerous mental and physical changes in the human organism from hour to hour, day to day, month to month, year to year, and age to age. This growth was long considered to follow a quite regular course from year to year, except in individual cases when its course was interrupted by sickness, poor food, mal-nutrition, worry, or some other like cause. We find, however, a vague but more or less real recognition of the more general periodic changes in human life in Hippocrates' division of life into seven stages, a division which was later employed by Shakespeare in his "Seven Ages" of man.

These general divisions continued to be recognized for several centuries, though the depth and profundity of the changes taking place, (especially between infancy and childhood and between childhood and youth), were but vaguely comprehended. It is only with the growth of scientific research along the lines of Biology, Genetic Psychology, Child Study, and Experimental Pedagogy that their great significance has been sufficiently recognized.

Besides these, many other growth rhythms have been detected. As early as 1859, E. Smith<sup>36</sup> showed in his "Analysis of Respiration" that breathing is at a maximum in spring and at a minimum toward the end of the summer and beginning of autumn.

Somewhat later, N. Finsen<sup>10</sup> found that the amount of haemoglobin in the blood also has periodic variations, showing a maximum in fall and a minimum in winter. This might be explained partly by the corresponding increase or decrease in the amount of air breathed; as the maximum amount of haemoglobin comes sometime before the mini-

imum of breathing, while the minimum of the former shows itself a short time before the minimum of the latter.

Following this, Lehman<sup>34</sup> through tests with a plethysmograph found that there are periodic variations in the strength of heart beats which agree with the variations in the haemoglobin content of the blood, in being greater in summer than in winter.

That the growth in height and weight of the child undergoes various periodic changes within the year was first discovered by Malling-Hansen, director of the deaf mute institute in Copenhagen. The occasion for its discovery was accidental. In the year 1882, Malling-Hansen changed the diet of all the boys under his care, and in order to discover the effects of this change on the physical development of the pupils, he hit upon the expedient of carefully weighing the boys daily. This he did with 130 boys from May, 1882, to Feb., 1886, and for the last two years of that period he also measured them daily with much care, taking elaborate precautions to secure accuracy and uniformity in all measurements. By this means he discovered that the height and weight of growing boys seemed to be subject to periodic variations which recurred year after year in the same manner.

Nearly all his tables in "Perioden im Gewicht der Kinder und der Sonnewaerme"<sup>29</sup> are based on the measurements and weighings of about 70 boys, from nine to seventeen years old, weighed from May, 1882, to Feb., 1886, and measured from Feb., 1884, to Feb., 1886. The children were weighed four times per day with the exceptions of vacations, each of which lasted six weeks, from the middle of July to the end of August. The pupils were weighed in groups of sixteen to eighteen, and the heights given are also of these groups. His data, therefore, show nothing as to changes in individuals. His results may be summarized as follows: The weight of a group of growing boys from nine

to sixteen years of age, has three periods of growth during the year,—a maximal, a middle, and a minimal. The maximal period begins in August and ends in the middle of December, lasting four and one-half months. The minimal period extends from the end of April to the end of July, lasting three months. During the maximal period, the rate of increase is three times as great as in the middle period. Almost the whole weight gained in the middle period is lost in the minimal period.

Respecting growth in height, he finds that the minimal period begins in August and lasts till the middle of November, three and one-half months. The middle period reaches from the end of November till the end of March, about four months. The maximal period extends from the end of March to the middle of August, about four and one-half months. The daily rate of gain in height in the maximal period is two and one-half times as great, and in the middle period is twice as great as that of the minimal period.

It is also interesting to note here that Dr. Winifred Hall, of Haverford College, develops the same law of separate rhythms for height and weight during the larger periods before and during pubescence that Malling-Hansen found for the seasons. Dr. Hall finds that when the vertical dimensions of the body are undergoing acceleration of their rate of growth, the horizontal undergo a retardation of their growth, and conversely. The same author also claims that growth in height is due largely to an increase in length of the long bones. G. Stanley Hall claims that adults tend to grow thin when children grow tall, and to grow thick when children grow heavy; and suggests that by using the former period for cures, fleshy people can aid nature.

Many other annual or seasonal rhythms of life are known to science, among the more common of which we find the migration of birds, the hibernation of various animals, the running of fishes, the shedding of winter coats of fur and

feathers, and the mating season of animals of all sorts. We see, therefore, that Malling-Hansen was in the presence of a great biological law of rhythmic growth which depends for its existence on the very nature of the universe itself.

The findings of Malling-Hansen have been corroborated in the main by Dr. Schmidt-Monnard in Halle, Germany. Besides this, various supplements to these investigations have been made, regarding the periodicity of mental and physical development, and the periodic changes in mental and physical abilities, which seek to discover the nature of any existing paralellisms in physical and psychic functions and to discover the probable causes of their periodic variations. A full account of such investigations will be given in the following pages.

## CHAPTER II.

### SEASONAL PERIODICITY IN MENTAL AND PHYSICAL ABILITIES.

#### I. PERIODICITY OF ATTENTION. (SCHUYTEN)

(1) *Method.* During the school year 1893-4, Dr. M. C. Schuyten, director of the pedagogical laboratory at Antwerp, made a series of investigations concerning the periodic variations in the power of attention. The following data are taken from a report of his work given by Marx Lob-sien in his "Schwankungen der Psychischen Kapazität."

Two upper and two lower classes of boys and girls from eight to ten years of age were tested monthly to discover any periodic variations in their power of attention. The children were tested four times on each test day. To avoid any disturbance from other classes, those to be tested were isolated during the tests.

Each child sat with his Flemish reader open before him. At a given signal which always remained the same, the children began to read silently. The experimenter noted by observation those who were not attentive, those who stopped reading, those who raised the eyes from the pages, and those who were continuously attentive through five minutes, the length of the test. The investigation was begun in March, 1893, and continued for one year except during the months of August and September, when the long vacation intervened.

(2) *Results.* The general summary of the results for the year is here given:

Month	Jan.	Feb.	Mch.	Apr.	May.	Jun.	July	Oct.	Nov.	Dec.
Per cent. of Attention										
Energy	68	63	77	69	64	42	27	48	62	67

He notes the greatest difference between March and July. Upon these results he bases the following conclusions:

1. The power of attention in children is inversely proportional to the atmospheric temperature.
2. It is greater in the higher than in the lower classes.
3. It is greater in girls than in boys.
4. It diminishes from 8:30 a. m. to 11:00 a. m., and again from 2.00 p. m. to 4:00 p. m., but it is always greater at 2:00 p. m. than at 11:00 a. m., and less than at 8:30 a. m.

(3) *Verifying Tests.* In order to satisfy himself that the results were valid, Schuyten made a second set of experiments using the same general method of study as before with one exception, he began the tests in April instead of March. The final summary of the results from the verifying tests is here given:

Month	Jan.	Feb.	Mch.	Apr.	May	Jun.	July	Oct.	Nov.	Dec.
Per cent. of Attention										
Energy	59	54	54	51	45	42	35	48	51	57

Various comparative tables are given some of which are here reproduced:

#### TESTS TAKEN AFTER A REST

Month	Jan.	Feb.	Mch.	Apr.	May	Jun.	Jul.	Oct.	Nov.	Dec.
Per Cent.										
A. M.	64	59	57	55	47	45	39	52	55	62
P. M.	59	55	57	52	49	47	42	50	51	58

#### TESTS TAKEN BEFORE AND AFTER A REST

Month	Jan.	Feb.	Mch.	Apr.	May	Jun.	Jul.	Oct.	Nov.	Dec.
Per Cent.										
Before Rest	56	51	50	43	42	36	29	46	48	55
After Rest	61	57	57	53	49	46	40	51	53	60

#### TESTS AFTER REST, HIGH AND LOW CLASSES

Month	Jan.	Feb.	Mch.	Apr.	May	Jun.	Jul.	Oct.	Nov.	Dec.
Per Cent.										
High Class	61	56	55	52	49	47	41	52	52	59
Low Class	61	57	49	54	48	45	40	52	54	60

## TESTS AFTER REST, BOYS AND GIRLS

Month	Jan.	Feb.	Mch.	Apr.	May	Jun.	Jul.	Oct.	Nov.	Dec.
Boys	61	56	57	54	49	45	41	50	53	60
Girls	61	58	57	53	41	46	40	51	53	59

From these results Schuyten concludes:

1. That the results of the first experiment are verified by the second.
2. Rest has a good influence on attention.
3. In winter, a higher per cent. is obtained after the morning rest than after the afternoon rest; in summer the reverse is true. This would show that intermissions are more beneficial in summer than in winter.
4. Recess periods have more influence on the lower classes than on the higher classes.
5. Recess periods are more beneficial to boys than to girls.

(4) *Criticism.* This work by Schuyten is a pioneer in its field and as such deserves great credit. There are several probable sources of error, however, on the basis of which we may question the universal validity of his results. The first is in regard to the means employed. It is entirely probable that the pages used in the Flemish readers were not equally interesting to all the children in the different classes so that the material lacked uniformity. Schuyten himself admits that this may be true.

There may also be a question raised as to the usefulness of the method of recorded observation in measuring the attention of children in a large group. The author judged only by appearances without checking the results by the introspection of the children. Aside from the fact that these results do not easily lend themselves to quantitative measurements, it is possible that many times only the signs

of attention were mistaken for the fact of attention. Schuyten had his doubts about this point, and Lobsien doubted so strongly that he devised a new method which aimed at uniformity of material, and gave a record which lent itself more readily to quantitative measurement.

In regard to the results from Schuyten's "Verifying Test," I can scarcely agree with him that it proves the results of the first experiment. It seems to me that in Schuyten's first tests, we see in the high level for March the effects of novelty rather than a true index of the ability or power of attention. This shows the great need for preliminary tests in any experimental investigation in order to perfect the method, and to eliminate practice effects. As none were given, it seems reasonable to suppose that the results of the verifying test give a truer range of the variability of attention than do the results from the first set of tests. These later results seem to show a crest in January rather than in March.

Concerning his conclusions for age and sex differences, though we grant the validity of his results, the resulting differences are not large enough or persistent enough to be the basis for any such general conclusions as he has made.

Finally, Schuyten is not warranted in drawing any such sweeping conclusions from four tests made on the same day, and once each month. The work of other investigators shows that the records from such a small number of tests per month contain many accidental errors which tend to minimize the validity of the results, so that what seems to be seasonal variations may be due in a large part to accidental causes.

The results from these experiments are shown graphically in Fig. 2, where they are compared to his results on periodicity in muscular energy.

## 2. PERIODICITY IN MUSCLE STRENGTH. (SCHUYTEN)

(1) *Method.* Schuyten next tried by experiments to

discover the annual variations in and the annual increase of muscle strength in boys and girls. Accordingly he tested the grip strength of a group of children of both sexes in Antwerp during the school year from October, 1898, to July, 1899. These tests were given on the fifteenth of each month at 2:15 p. m. In all 5400 results were tabulated. The Elliptical Dynamometer was used for both pushing and pulling tests, first with the right and then with the left hand. The children were encouraged to wager so they would use all their strength.

(2) *Results.* The following table shows the results for both sexes, pushing and pulling:

Month		Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	Jun.	Jul.
Boys	Pull	438	469	487	491	511	490	515	534	558	582
	Push	139	149	155	156	162	156	166	170	178	185
Girls	Pull	439	436	452	453	486	481	481	481	488	506
	Push	138	139	144	144	155	155	153	154	155	161
Both	Pull	436	455	469	474	497	486	499	509	524	547
	Push	139	145	149	151	158	155	159	162	167	174

One result which is everywhere shown is the downward curve of capacity in March, only one case showing a slight increase. Commenting on this the author gives the following table which shows the monthly increase or decrease in physical strength:

#### MONTHLY INCREASE OR DECREASE IN PHYSICAL STRENGTH (Lobsien)

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	Jun.	July
Boys	—	3.1	1.6	0.4	1.9	—2.0	2.6	1.9	2.4	2.4
Girls	—	0.3	1.0	0.1	0.5	—0.5	0.0	0.2	0.6	1.8
Average	—	1.8	1.6	0.1	2.4	—1.1	1.3	1.0	1.5	2.3

(3) *Verification.* Not wholly satisfied with these results Schuyten made a supplement to them in the year following. In this investigation he tried to eliminate the ef-

fects of growth and habit by testing a different group of children each month. In several public schools of Antwerp, he grouped the children according to the month in which they were born. Each child began the tests at the age of nine years and nine months, those born in January being tested in October, those born in February being tested in November, etc. Each monthly group was tested three times during the first half of the month, first with the left hand and then with the right hand. The results from 45,453 records are shown in the tables below. These tables show the average pulling strength for both hands combined. The children in the first table were born in the year 1889, and those in the second table were born in 1890.

	1889		
Month	Boys	Girls	Aver.
Jan.	47.0	38.4	43.0
Feb.	44.1	38.7	41.3
Mch.	44.9	36.0	38.8
Apr.	46.9	37.9	41.8
May	47.0	38.6	42.7
Jun.	50.6	40.1	46.0
Jul.	49.9	39.8	44.4
Oct.	44.1	36.2	39.1
Nov.	45.7	37.2	40.9
Dec.	46.5	38.1	42.4

	1890		
Month	Boys	Girls	Aver.
Jan.	39.9	34.1	36.6
Feb.	38.4	34.3	36.1
Mch.	35.9	32.8	34.3
Apr.	39.1	34.0	36.3
May.	41.2	33.9	38.4
Jun.	43.5	35.7	38.7
Jul.	44.3	36.4	39.5
Oct.	38.2	32.6	35.1
Nov.	38.0	33.1	35.3
Dec.	39.5	34.1	36.6

From the results of these two investigations, Schuyten concludes that there are four distinct periods for muscular energy as follows:

1. A falling period from January to March,
2. A rising period from April to June,
3. A decrease from July to September,
4. An increase from October to December.

(4) *Criticism.* Of these two investigations concerning periodicity in muscular energy, Schuyten bases his conclusions almost entirely on the second or verifying test. Of course it is true that the effects of practice and of yearly growth are largely eliminated by this, and the results from

the different months are comparable. The only drawback is that the groups tested were not homogeneous or uniform, and the individual differences found might destroy the value of the most important variations shown in the results.

While recognizing that this criticism might be made, Schuyten minimizes its effect, and entirely neglects it in drawing his conclusions. A series of preliminary tests made on the monthly groups might have been arranged so that the individual differences could have been almost entirely eliminated. That no such preliminary tests were given seems very unfortunate, and casts the only doubt on what is otherwise a very carefully conducted experiment.

### 3. PERIODICITY IN PRIMARY MEMORY. (LOBSIEN)

(1) *Method.* Lobsien criticised Schuyten's conclusions on the grounds (1) that the tests were not homogeneous or of the same degree of difficulty, and (2) that the variations noted in the tests are not entirely due to changes of the seasons or to changes in the atmospheric temperature. He therefore sought to supplement and verify the work of Schuyten in a similar investigation. In gathering the data, experiments were made on boys and girls in the public schools of Kiel, Germany, from 8 to 14 years of age. They were made on the fifteenth day of each month from September, 1901, to June, 1902, July and August being vacation months.

(2) *Procedure.* Lobsien's work is limited to the study of primary memory for lists of ten words involving both visual and auditory imagery, which are here reproduced:

#### LOBSIEN'S WORD LISTS

##### VISUAL

###### A

1. Sonnenlicht
2. Fensterscheibe
3. Wandteller
4. Handspiegel
5. Himmelblau

##### ACOUSTIC

###### A

1. Gesang
2. Gebell
3. Summen
4. Sausen
5. Rasseln

6. Abendstern
7. Taubenhaus
8. Ofenschirm
9. Turmuhr
10. Bierglas

## B

1. Abendrot
2. Brieftasche
3. Federbusch
4. Fensterkreuz
5. Feuerwerk
6. Handschrift
7. Mondscheibe
8. Gotteshaus
9. Kirchtum
10. Streichholz

## C

1. Kohlschwarz
2. Morgenstern
3. Nachtmütze
4. Olzweig
5. Ofenrauch
6. Rotfuchs
7. Freimarke
8. Angesicht
9. Vorschrift
10. Lampenglas

## D

1. Feuerschein
2. Morgenröte
3. Leuchtkeugel
4. Postkarte
5. Schattenbild
6. Blitzstrahl
7. Georgine
8. Spiegelbild
9. Zifferblatt
10. Hangenlampe

6. Lispeln
7. Poltern
8. Lärmen
9. Donnern
10. Sprechen

## B

1. Drohnen
2. Stampfen
3. Krachen
4. Bellen
5. Sauseln
6. Rauschen
7. Knistern
8. Klirren
9. Kreischen
10. Blasen

## C

1. Ticken
2. Weihern
3. Meckern
4. Gackern
5. Krahen
6. Brüllen
7. Klingen
8. Pfeifen
9. Trommeln
10. Klappern

## D

1. Zirpen
2. Rufen
3. Weinen
4. Scharren
5. Seufzen
6. Knallen
7. Puffen
8. Schluchzen
9. Winseln
10. Klopfen

The word lists were spoken plainly after which each pupil was asked to write the words in a list at once. Lobsien tabulated the results separately for girls and boys and for each age.

(2) *Results.* The results as shown in the accompanying

tables include 8900 records and the experiments are based on two important activities of the mind, primary memory and attention. The result are here given:

GIRLS		
Month	Visual Imagery	Auditory Imagery
September	2386	2515
October	2489	2138
November	3964	2605
December	2686	2257
January	2080	2325
February	2810	2322
March	2847	2761
April	2483	2262
May	2640	2641
June	2523	2530
BOYS		
Month	Visual Imagery	Auditory Imagery
September	2328	2492
October	2073	1894
November	2063	2218
December	2142	2243
January	2053	2319
February	(1965 Estimated)	(1968)
March	(2102 Partly lost)	(2161)
April	2011	2266
May	2246	2400
June	2384	1967

The curves for boys and girls are much alike. The middle energy height is much higher for girls than for boys. In general these curves show a high period or crest around December and January, and a trough or depression in February and April. The visual tests show a curve which is higher in the first part than in the last part, a fact which he considers the more remarkable because the pupils should improve with practice. The acoustic curve for girls in general parallels the visual curve, but always has a smaller value. There is very little difference in ages, except that psychic energy tends to become more uniform with age.

The results for boys show the highest value in the first tests in September, and at the end of the tests in June. A

second slight elevation is found in January. The visual curve is nearly always less for boys than the auditory curve, and the variations are more opposite than parallel. Boys agree with girls in the depression in the visual curve around July. They also agree with girls in showing a high value in December and January and corresponding depressions in February and April. The first half of the year seems the best for boys. On the whole, psychic energy is higher for girls than for boys, but boys show a higher low point than girls.

The table showing the monthly changes in psychic capacity shows almost a regular rise and fall for the months following each other for the girls, while for the boys, the rhythmic changes extend over a somewhat longer period.

(3) *Criticism.* The work of Lobsien while very carefully worked over seems to be somewhat questionable both in the materials and the procedure. While the method was new, the word materials are so much alike in form that the memory images undoubtedly interfered with one another. A careful survey of the word lists will bear out this statement. Then again, there are so many accidental factors which enter into mental abilities, due to time of day, temperature, individual daily results, etc., that it is doubtful in the extreme that the results from tests made but once per month are a true index of any but accidental factors, and that the seasonal rhythms cannot be discovered from tests taken but once per month. The mere fact that such a large number of persons was tested cannot overcome this source of error in the procedure. The validity of his conclusions that "Physical and psychic development do not parallel," is destroyed by the errors in the data.

#### 4. PERIODICITY IN PHYSICAL STRENGTH. (LEHMAN AND PEDERSEN)

(1) *Aim.* Lehman and Pedersen made a much more careful study of periodicity than either Schuyten or Lobsien.

By means of a long series of experiments they attempted to discover the effects of the weather on muscle strength. As the experiments covered a period of nearly two years, many of the data show seasonal variations. We will, therefore, describe the more general variations here, reserving only some of the details for the section on weather effects. The experiments were made partly on public school pupils in Copenhagen, and partly on three grown people. As the apparatus and procedure used for the children was different from that used for the adults, I will describe the method and procedure for each group by itself.

(2) *The Individual Tests.* Most of the individual tests were made by three persons, Dr. Lehman, Dr. Pedersen, and Miss J. Each used the same individual dynamometer throughout the tests, one being provided for each. As the dynamometers differed, no comparisons were made between the results, these being referred to as I, II, and III. In the tests, each person always used his own dynamometer, Miss J. III, Pedersen II, and Lehman I. The tests were taken always with the left hand by Lehman and Miss J. and with the right hand by Pedersen, who was left handed. Five tests were made, with not less than thirty seconds between, immediately after rising each day.

(3) *The School Tests.* In the School Tests, five groups of children were used.

Group I, consisted of twenty-one pupils between 12 and 13 years of age. This group was tested one day (always the same day) each week, between 9 a. m. and 10 a. m., on each test day from January 1 to April 21, 1904.

Group II, consisting of twenty-one pupils between 10 and 11 years of age, were tested once each week as above from August 12, 1904, to March 31, 1905.

Group III, consisting of eighteen pupils between 11 and 12 years of age, were similarly tested once each week from August 12, 1904 to March 31, 1905.

Group IV, consisting of the twenty-one pupils between 13 and 14 years of age, were tested between 9 a. m. and 10 a. m. once each week from August 12, 1904, to March 31, 1905.

Group V, consisting of ten pupils between 12 and 13 years of age, were tested between 10 a. m. and 12 m. on each school day from January 12, 1906, to June 1, 1906, and again from August 12, 1906 to December 21, 1906.

In these tests, Lehman's Ergograph was used. The tests were carefully controlled and the children were urged to compete with each other for high records. Before taking the tests each boy was asked to dry his hand on a towel. Each boy then took four grips with an interval of four seconds between at a uniform tempo. The averages of these four trials are shown in the tables for results. Each boy used only his most dextrous hand in making records.

Before the real tests, each boy was allowed to make a number of trials, so as to learn to grip in a uniform tempo, which was the same for all so far as possible. Whenever a pupil was absent, ill, or otherwise indisposed, or did not wish to grip (which happened very seldom), an average grip was worked out for him from the days preceding and following, and put in its place. Pupils who were absent for a long period were not included in tabulating the results.

(4) *Results.* The more general of the results from the individual tests, are as follows:

The curve of Lehman (who was 47 years old), "sinks in the fall to the middle of December, then rises, first slowly, then more quickly to the end of June. It sinks during July and August, rises abruptly in September, and sinks gradually to the end of the tests in December."

The curve of Pedersen (who was 36 years old), is very "similar to that of Lehman during most of the time."

The curve of Miss J. (who was 18 years old), and Group V of the boys, who were also tested from January to Decem-

ber, "show stationary periods where Lehman and Pedersen show a decrease," and a continuous rise through the remainder of the year.

The results from each of the groups of boys are presented in the following table. In this table the values for the five groups of boys are given in kilograms, for each age separately. They are also combined and worked out in per cent., the January values being taken as the base, and compared with light strength and with variations in temperature.

TABLE I

Date	Phot.	L.	P.	J. Boys	Date	Phot.	L.	P.	J. Boys
Oct. 1	35.2	38.5			May 19	46.7	40.6	51.5	41.3 32.0
" 11	36.2	38.2			Jun. 8	47.8	42.7	50.3	44.8 32.1
" 21	33.7	38.1			" 18	48.6	42.8	50.4	46.3 33.0
" 31	31.9	37.7			" 28	45.8	43.3	50.3	45.0 33.7
Nov. 10	31.2	37.9			July 8	46.0	41.9	51.0	47.2
" 20	28.9	38.2			" 18	44.9	42.0	50.5	45.8
" 30	25.9	37.6			" 28	49.1	41.6	53.0	43.2
Dec. 10	25.6	37.0			Aug. 7	47.9	41.3	53.3	46.6
" 20	25.4	37.3			" 17	45.4	40.1	53.8	46.6 33.0
" 30	26.9	38.7			" 27	48.1	41.3	52.7	46.5 33.7
Jan. 9	24.0	37.9			Sept. 6	44.8	43.7	52.3	46.1 34.1
" 19	27.8	38.3			" 16	41.6	46.8	52.5	47.9 33.9
" 29	28.1	37.7	42.4	26.2	" 26	41.0	45.3	50.9	49.9 34.3
Feb. 8	31.5	38.9	44.2	27.6	Oct. 6	37.8	45.1	53.0	50.8 35.2
" 18	29.7	38.9	47.8	27.8	" 16	39.3	44.8	53.7	49.9 34.3
" 28	34.6	39.5	49.1	29.2	" 26	30.5	43.7	51.6	49.0 36.4
Mh. 10	35.5	39.8	50.7	29.5	Nov. 5	29.0	43.7	51.5	48.3 37.3
" 20	36.4	39.2	51.7	30.3	" 15	32.8	44.1	52.4	48.7 36.9
" 30	41.4	40.5	52.1	37.2 30.5	" 25	30.0	43.0	52.3	51.1 37.2
Apr. 9	45.3	41.0	51.9	38.7 31.3	Dec. 5	29.1	42.5	52.6	51.5 37.0
" 19	37.5	40.5	53.1	38.4 30.5	" 15	28.3	42.0	52.1	49.2 37.2
" 29	43.4	40.5	52.6	42.0 31.4	" 25		42.0		
May 9	47.4	40.1	55.6	42.9 31.8					
" 29	43.3	42.0	50.2	41.1 33.1					

The above table shows the weekly averages of Lehman, Pedersen, Miss J., and Group V of the boys when compared to changes in the strength of sunlight as recorded by a Steenstrup photometer.

TABLE II

Month	1904 10-11	1904 11-12	1904 13-14	1904 12-13	1903 12-13	All Per C	Temp.	Light
May	19.6					73.7	10.2	45.8
June	21.0	24.2	27.0			80.3	14.5	47.4
July							16.1	46.7
Aug.	22.8	25.7	28.6			86.0	15.7	47.1
Sept.	22.0	25.8	27.9			84.4	12.8	42.5
Oct.	25.6	29.3	31.8			95.3	8.0	34.3
Nov.	26.5	29.6	33.9			100.3	3.7	28.7
Dec.	26.6	29.8	33.9			100.7	0.8	26.0
Jan.	26.6	29.2	33.9	22.7	25.9	100.0	-0.1	26.6
Feb.	27.6	29.6	35.2	23.0	27.9	103.6	0.0	31.9
Mch.	28.2	31.2	36.6	25.6	29.8	109.7	1.2	37.8
Apr.				25.4	31.0	115.8	5.7	41.7
May					32.1	124.0	10.2	45.8
June					33.1	127.7	14.5	47.7
July							16.1	46.7
Aug.					33.5	129.3	15.7	47.1
Sept.					34.1	131.6	12.8	42.5
Oct.					35.5	137.0	8.0	35.9
Nov.					37.2	143.5	3.7	30.6
Dec.					37.1	143.2	0.8	28.7

The authors describe the results by saying that muscle strength begins to rise in January, with light strength, and shows a decided growth through February and March, while the temperature is almost constant, and much lower than that at which muscle growth stopped in November. It still grows in May, when light has attained its maximum, but in June and especially in July and August, when heat reaches its maximum, growth in muscle strength stops entirely, and starts again in September, as soon as the heat decreases somewhat. The fact of increasing muscle strength with falling temperature was noted in both Lehman and Pedersen, but in growing persons the growth hides this effect.

The conclusions are as follows: "The stronger light is, the more favorable the actinic rays are to muscle strength. Heat has an individually varying and perhaps a movable

optimum so that both low and high temperatures are depressing to muscle strength. From the joint influence of these two factors there arises the yearly periodical variations of muscle strength."

(5) *Criticism.* This work is very carefully and systematically done. It seems possible, however, that the authors were a little over-zealous in attempting to explain the phenomena of variations in muscle strength as due entirely to external conditions. As to its aim, means and methods of procedure, there is very little to criticise. The results, also, are given in detail, so there may be no question concerning them. It seems, however, that the authors have drawn conclusions not wholly warranted by the facts.

In the first place, the authors find a "very abrupt rise in muscle strength in September." This seems to be a little unusual and needs analysis. Of the four sets of records, shown in the first table, but one person, Lehman, shows such a tendency. Most of the groups of boys in the second table show a drop in September, a large rise in October, and remain almost stationary until January. This large rise in September is a phenomenon which is not found by any other investigator, and the fact that there is almost no increase in three groups of growing boys during three or four months from October to January, would suggest that some unusual influence was present, such as a changed adjustment of the ergograph or some internal cause. In my own experience, I know that merely adjusting a machine or perhaps oiling it, makes a great difference in the records. In the presence of such a fact, the authors should have studied the records in detail for errors and considered such facts in the conclusions concerning the causes of the variations found. It would seem that practice effects plus growth alone would show some sort of increase in the abilities of growing boys during three or four months.

In regard to the beneficial effects of light strength and heat strength, the authors avoid many seeming contradictions in their conclusions by clever explanations. In order to explain constant growth in muscle strength they try to find some favorable influence for nearly all times of the year, so they hit on the combination of light and heat. From January to May light is beneficial; from September to November normal heat is favorable, while in December decreasing heat is unfavorable. When confronted by these seeming contradictions, they explain them on the basis of a movable optimum above or below which heat is unfavorable. This is perhaps one of the most important ideas in the whole account. While there seems to be no doubt about the influence of sunlight and especially of changes in temperature on muscle strength, it seems to me that many other factors, such as food, clothing, and general manner of life should be included as causal factors. Though the authors tried to eliminate these effects as far as possible in the cases of Lehman and Pedersen by taking the tests shortly after rising, they should not have neglected them entirely.

Concerning the effects of air pressure, a report of which may be found in the section on weather effects, the facts seem to be very well established. Here, as in the case of temperature, they suggest the theory of an individual optimum, above or below which atmospheric pressure is injurious to muscle strength. This question of an individual optimum for both air pressure and temperature is very important, and should be further investigated. As to the mental tests, also reported under weather effects, we will pass them without criticism as the authors make no positive claim for their data. Their remarks on the methods of studying mental abilities and on showing the results graphically, are well and carefully thought out, and are well worth study.

All through the article the authors are very sane in their treatment of results, and their explanation of the usefulness

of the formulas used in statistical studies is very valuable. On the whole, it is the most scholarly work on periodicity which I have found, and must be taken into account by any who engage in a similar study.

#### 5. SEASONAL VARIATIONS IN DIURNAL PERIODICITY. (KUHNES)

(1) *Method.* Kuhnes made a very thorough investigation of diurnal periodicity in physical strength while a student at New York University, the results of which I have taken from an unpublished thesis. In these tests the Smedley Dynamometer was used. The tests, which were made mostly on himself, were taken seven times daily for 505 consecutive days. At each of the seven test periods, the average of three records for each hand was taken, the six tests being taken in three different positions, first with the left, then with the right as follows:

1—each hand hanging downward.

2—each hand held vertically

3—each hand held horizontally.

(2) *Results.* The principal results are given in the section on Diurnal Periodicity, but there are several statements in his "Summary and Conclusions" which are of value here. They are as follows:

1—The average diurnal course of efficiency is also the course of 88 per cent. of the days.

2—There is a distinct seasonal periodicity characterized by a maximum in December, a gradual decline through the winter with a minimum in February and March, a gradual rise during the spring, and a slightly higher one in autumn. There are marked fluctuations at the beginning of the spring and winter seasons.

3—There is a tendency of the curve of efficiency of one year to follow the general trend of the curve for the preceding year.

(3) *Criticism.* The work of Dr. Kuhnes was done in a

very careful and painstaking manner. The method of checking was such as to eliminate all accidental or unusual grips; the average of forty-two grips being taken each day, (twenty-one with each hand), and the method and procedure were strictly uniform and well adapted for the purpose. The fact that only one person was tested, a young man of scholarly habits not physically strong but in good health, narrows the value of the results somewhat, but this is largely outweighed by the care and fidelity of the person taking the tests. The results from one test person carefully gathered are often of far more value than the results from a large number superficially tested. Next to the investigation of Lehman and Pedersen, this is perhaps the most important investigation which has yet been made.

#### 6. SUMMARY OF THE MAIN PROBLEMS OF SEASONAL PERIODICITY.

At this point it may be well to summarize the main problems and results of previous investigations of periodicity in mental and physical abilities, in order that they may help us to a birds-eye view of the problems to be solved. In this field we find a great diversity of opinion. There seems to be little doubt about the existence of seasonal rhythms in growth in height and weight, in blood pressure, and in haemoglobin content of the blood, as well as in muscle strength and in mental abilities. Though several investigators have studied the various aspects of the problem under a great variety of conditions and by a great variety of methods, the actual course of seasonal periodicity, its chief characteristics, and its most noticeable effects are still under discussion, and the knowledge of its causes is still far from satisfactory or complete.

In physical strength, Schuyten found for growing children a falling period from January to March, a rising period from May to June, a falling period from July to September, and a rising period from September to December. Lehman

and Pedersen found, for a group of growing boys and a young girl, a rising period from February to June, a stationary period from July to September, and a rise to December, with a stationary period from December to February. For adults, Lehman and Pedersen found a falling period from November to January, a rising period from February to June, a falling period from June to August, and a sharp rise in September, with a continued rise till November.

Kuhnes found a maximum in November and December, a minimum in February and March, a gradual rise through the spring and a slightly higher one in autumn.

These studies seem to show that the rhythms found for adults by Lehman and Pedersen and Kuhnes differ from those found for growing young people by Lehman and Pedersen, and by Schuyten, the curve for young people showing a stationary period where that for adults shows a decrease. The rhythm for adults seems to show variations a short time before that for young people and children.

In the mental tests, Schuyten found a crest in January, with a decrease to July, and an increase from October to January. Lobsien found a high level for primary memory around January, a low level for February and April, and a low level around October, with a rise to January. Lehman and Pedersen found the best results in a memory study, made on a group of children, in January, and in May, with a slight drop in February, June, and September. Many of these authors found more or less agreement between mental and physical abilities, and weather conditions. Lehman and Pedersen go so far as to say that the seasonal variations found by them are a direct result of the continued effects of temperature and the strength of sunlight. Other authors simply find that mental and physical abilities are more or less influenced by the weather. With these points in mind, we will proceed to the analysis of our original data on seasonal periodicity.

### CHAPTER III.

## AN ORIGINAL EXPERIMENTAL STUDY IN SEASONAL PERIODICITY

1. *Introduction.* During the school year from October, 1910, to June, 1911, the writer conducted an original experimental investigation concerning periodicity as shown in mental and physical tests. These tests were made on two groups of students in the first year of the Manual Training High School of Washington University, St. Louis, Mo. The tests were all made under the personal direction of the writer at hours ranging from 9 a. m. to 3 p. m., at a time when the classes came to his room for a study period. Many students took the tests for a part of the time, but only ten (referred to as the B. Division) took the tests daily throughout the entire period. Another group of twenty-two (referred to as the A. Division) took the tests once each week on Friday.

Owing to the amount of time consumed by these tests, it was not possible to give more than one physical and one mental test daily. The complete record of each of these tests will first be described separately, after which the results will be compared with one another, and with the results of other investigators of periodicity.

### 2. PERIODICITY AS SHOWN IN PHYSICAL TESTS.

(1) *Purpose.* The main purpose of these tests was to discover any periodic variations in muscle strength as shown by dynamometric tests in the course of a school year. A secondary purpose was to find, if possible, a verification of the work of Schuyten, Lobsien, Kuhnes, and Lehman and Pedersen.

(2) *Method.* As a basis for this investigation a series of tests was made for strength of grip, using the Smedley

Dynamometer. The tests were made daily on ten boys, and weekly on one man of 26 years of age and on twenty-one boys, all of the boys being between 13 and 19 years of age. They were made at varying times during the day between 9 a. m. and 3 p. m., except that none were made between 12 m. and 1 p. m. All records were made under my personal direction, and I was as careful as possible to keep the conditions uniform throughout the investigation.

(3) *Preliminary Tests.* In both the A. and B. Divisions, a series of preliminary tests was made for three days, during which time each subject found the correct adjustment for his hand and learned to use his strength to advantage. It was found that when the students took the tests always in the same order, only two re-adjustments of the dynamometer were necessary during the tests in each division. In this way the grip length of each subject was accommodated and the same adjustment was made each day for each pupil.

(4) *Procedure.* In making the tests each pupil was instructed to hold the dynamometer at arm's length, with the dial face upward. Each subject was allowed three trials, taken alternately for each hand, only the highest record for each hand being recorded. This allowed an interval of about 30 seconds between any two records for the same hand, so that the hand recovered from the effects of any strain before the next grip was taken. The subjects entered into the plan with earnestness and every one did his best, so far as the writer could discover, to keep the external conditions uniform.

(5) *Results.* In checking the results, the averages for each day and for each week were computed for each group, as was also the average of each pupil in the B. Div. for each week. When a pupil was absent, it was found necessary to count him in making up the daily averages, at his average made during the other days of the week. If a pupil was absent for a full week at a time he was counted

Div.	No.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	Avg.	High	Low	Greatest Variat'n
A	52	10.2	10.8	10.6	10.7	10.5	10.7	10.7	11.1	10.7	10.7	11.1	10.2	.9
B	10	9.1	10.	10.4	10.6	10.2	10.2	10.2	11.2	11.	10.4	11.2	9.1	2.1
Table III Memory Tests. A and B Divs. (15 Perfect Mark).														

Table IV Average Grip Strength for each Month. (A & B Divs.)

Div.	No.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	Avg.	High	Low	Gain
A	R	36.3	37.8	39.	40.	39.6	40.8	41.3	42.2	42.5	40.	42.5	36.3	6.2 Kg.
B	22L	32.7	34.7	35.8	37.	36.9	37.	38.5	39.1	39.9	36.8	39.9	32.7	7.2 "
All	10R	46.5	50.	52.9	54.2	54.1	54.6	56.4	58.9	59.2	54.1	59.2	46.5	12.7 "
Avg.	L	42.7	46.4	49.7	51.4	51.2	52.7	54.3	55.1	57.2	51.2	57.2	42.7	14.5 "
	32R	39.5	41.6	43.3	44.5	44.1	45.1	46.	47.	47.7	44.3	47.7	35.9	8.2 "
	L	35.8	38.4	40.1	41.5	41.3	42.	43.4	44.1	45.9	41.4	45.9	35.8	10.1 "

each day at his average for the preceding week. In this way the absent pupils could not affect the averages, while if a pupil whose record was either above or below the class average was omitted from the records for one day, his absence might affect the class average very decidedly. The record of any pupil who was absent for two full weeks at a time was excluded in making up the records.

The monthly averages of both the A. and D. divisions for grip strength are found in Table IV. They show unmistakably the presence of a seasonable rhythm. We find a gradual increase in strength of grip for each hand from October to January, a slight decrease for each hand in February, a small increase in March followed by a continuous increase till June when the tests ended.

The same results may be seen in Table V for weekly averages. The variations in the first three weeks are due to the fact that several boys in each group gripped so hard that they injured their hands. The large initial increase is also partially due to practice. We see, however, that the period from October to the middle of January, is favorable. Then comes a period of depression until March, and a period of gradual increase until the end of the tests in June.

The same results may be observed in Tables VIII, IX, and X, where, with two or three small exceptions, we find low records for the month of February for both hands at all ages. A nineteen and a twenty-six year old subject both agree in showing a practically stationary period from December until March instead of a drop in February, otherwise they agree with the seasonal rhythm of the younger boys. These facts seem to agree with the results of other investigators on adults in showing a rhythm for adults which differs slightly from that of growing children, showing a stationary period where the growing children show great fluc-

Table V. Weekly Averages of Grips and Memory. A and B Divs.

Date	1910	$\frac{1}{14}$	$\frac{1}{21}$	$\frac{1}{10}$	$\frac{1}{28}$	$\frac{1}{4}$	$\frac{1}{11}$	$\frac{1}{11}$	$\frac{1}{18}$	$\frac{1}{25}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{28}$	$\frac{1}{13}$	$\frac{1}{20}$	$\frac{1}{27}$	$\frac{2}{3}$	$\frac{2}{07}$
A Div.	R	36.	35.4	37.4	37.2	37.1	38.3	38.7	37.9	38.1	39.2	38.8	39.6	40.2	40.1	38.9	39.9	38.9	39.0
	L	33.1	31.2	33.9	33.7	34.	35.6	35.5	34.8	35.7	36.9	35.9	36.9	36.5	37.6	36.5	37.0	36.5	37.0
	M	8.8	10.6	11.1	11.2	10.9	10.5	10.7	10.1	10.3	10.	12.1	10.7	10.	11.7	10.3	11.5	10.3	11.5
B Div.	R	44.9	48.7	45.9	49.2	49.2	50.7	51.	52.2	52.2	53.2	53.8	54.	54.5	54.2	54.1	54.3	54.1	54.3
	L	42.	44.5	42.1	44.5	45.7	46.8	48.6	49.2	49.2	50.	50.3	51.1	51.7	51.4	50.6	50.9	50.6	50.9
	M	9.	9.2	9.	10.5	9.1	10.3	10.3	10.3	10.3									
Date	1911	$\frac{2}{17}$	$\frac{2}{24}$	$\frac{2}{3}$	$\frac{3}{10}$	$\frac{8}{77}$	$\frac{8}{24}$	$\frac{8}{31}$	$\frac{4}{7}$	$\frac{3}{31}$	$\frac{7}{21}$	$\frac{4}{28}$	$\frac{5}{5}$	$\frac{5}{12}$	$\frac{5}{19}$	$\frac{5}{26}$	$\frac{9}{9}$		
A Div.	R	39.9	39.9	40.6	40.5	40.4	40.9	41.9	42.9	41.9	40.9	41.9	41.9	42.2	42.3	42.5	42.5		
	L	37.5	37.8	37.3	36.4	36.8	37.1	37.8	39.5	38.8	37.5	37.8	38.5	39.1	38.8	40.	39.9		
	M	9.1	11.1	10.1	10.6	11.2	10.6	10.4	10.4	10.4	11.1	10.9	11.2	11.6	10.8	10.7	10.9		
B Div.	R	54.5	53.9	53.3	54.7	54.8	54.9	55.3	55.3	56.6	56.7	57.1	58.3	58.7	59.4	59.	59.2		
	L	51.4	51.9	52.2	52.5	53.	52.5	53.2	54.	54.1	54.1	54.9	54.9	55.5	55.4	55.4	57.2		
	M	9.8	10.	9.8	9.6	10.3	10.8	10.4	10.8	10.9	10.7	10.9	11.6	11.	11.	11.2	11.		

Table VI. Memory and Grip. A Division.

	Oct	Nov	Dec	Jan	Feb	Mch	Apr	May	June
R	36.3	37.8	39.0	40.0	39.6	40.8	41.3	42.2	43.5
L	32.7	34.7	35.8	37.	36.9	37.	38.5	39.1	39.9
M	10.2	10.8	10.6	10.7	10.5	10.7	10.7	11.1	10.7

  

	Oct	Nov	Dec	Jan	Feb	Mch	Apr	May	June
R	46.5	50.	52.9	54.2	54.1	45.6	56.4	58.9	59.2
L	42.7	46.4	49.7	51.4	51.2	52.7	54.3	55.1	57.2
M	9.1	10.	10.4	10.6	10.2	10.2	10.8	11.2	11.

Table VII. Memory and Grip. B Division.

tuations, some showing an increase while others show a decrease.

### 3. PERIODICITY AS SHOWN IN PRIMARY MEMORY TESTS.

(1) *Purpose.* The main purpose of this investigation was to discover any periodic variations in mental abilities as shown in primary memory tests, given through a school year. A secondary purpose was to see how the variations compared with those found by other investigators of mental periodicity, and how they compared with the results from the dynamometric tests given to the same groups of students, on the same days, at the same hours, and during the same school year.

(2) *Method.* As a basis for this investigation, a series of tests was made to discover the ability of the two groups already referred to as the A. and B. divisions in the dynamometric tests, to reproduce three series of four, five, and six numbers of two digits each, immediately after they were read by the author. The tests were given immediately following the dynamometric tests. The group to be tested was seated in front of the investigator. At a given signal all of the students were requested to come to attention.

(3) *Procedure.* A series of four numbers, as 84-26-47-32, was read at the rate of one per second. At the close of each series, the students were allowed 15 seconds to write the series of numbers in the order of presentation, on a record blank provided for the purpose. This blank bore the name of the pupil and of the division, the time of day, date, character of the day, and the result of the dynamometric tests which had just been given. Fifteen seconds after the four numbers were written, at a given signal, a series of five two place numbers was read at the same rate as before. Then after waiting fifteen seconds for the pupils to write the series of five numbers on the record blanks, the attention signal was given, followed by six two place numbers at the same rate as before. After the pupils had written the series

of six numbers, they were asked to give any facts which helped or hindered them in writing the numbers, on the reverse side of the record sheet. The time of day, the character of the day in general and the temperature were then recorded along with any interesting introspections of the students, after which the records were collected. In estimating values, a number correctly given in its proper order was counted one point. A number rightly given but in the wrong order was counted one-half point. A number which had one digit correctly given was also counted half a point. The total score that could be made, therefore, was 15 points.

(4) *Preliminary Tests.* In this investigation, as in the one on muscular periodicity, a series of preliminary tests was given on three days. The purpose of the experiment was explained to the pupils, who entered into the spirit of the investigation with enthusiasm. As in the dynamometric tests, no one was asked to take the tests unless he so desired. In this experiment, also, absent students were counted at their average for the week, or if absent for a whole week, at their average for the preceding week. Those who were absent for more than two consecutive weeks were dropped from the investigation.

(5) *Results.* In this investigation, the averages for each day, each week, and each month, were computed both for the individuals, for all ages, and for each group as a whole.

The monthly variations for primary memory for both the A. and B. divisions are shown in Tables III, XI and XII. The tables for the B. division show a characteristic curve similar to the curve for muscular growth, that for the A. division does not show the same characteristics. The only striking similarity is found in the depression for February, a depression which is found in all the monthly curves for both mental and physical tests. If we examine Table XI we find this same depression for all

ages in February and March. The same depression is found in nearly all ages of the A. group (Table XII), except the two oldest subjects. Here we find the depression in January and March instead of February, as with the younger boys. The only other exceptions are two boys, both very bright and very nervous, at age 13-14 whose records were high through all the year. The high record for the A. division in November is due to an exceptionally high average of the two boys mentioned, for the month. The high record for the A. division for May and June was due largely to the individual record of an 18-year-old boy. During that time this particular boy was under a very high nervous tension. He was a part owner of an airdome which opened about that time, and he spent his evenings there until nearly midnight. He was old for the class but very bright. He had been out of school for about four years just preceeding this time. His increase in ability was therefore due very largely to habit and effects of practice, and was phenomenal. He was very thorough and painstaking, and his record shows what a year of conscientious study can do in sharpening a boy's mental ability.

With the exception of the two older students noted above, the A. division consisted of boys who had been in school continuously, and as a whole they showed very little change as a result of practice. They were all taking the Latin Course. The B. division was almost exactly opposite in composition. They were taking the English Course, and in general were more mature. Only two of the ten had attended school continuously. The others had all been at work for at least one term since graduation from a grammar school, and two had been out of school for three years preceding. In the B. division, therefore, we find that the low record for October was quite general. Then as a result of practice largely, it makes a very noticeable increase during the year, reaching a higher level than is reached by the A. division.

The very high records for April, May, and June, were due to the efforts of two very bright boys, both of whom had been out of school during the two years next preceding. The rise of these two boys, as well as that for the whole B. division, was due to the same cause as that of the nineteen-year-old in the T. division mentioned above—earnest application. If we eliminate these special cases and the practice effects, we find that the curve for the B. division Memory Tests becomes more nearly level, the one outstanding feature being a slight drop sometime in January and February. We must conclude, therefore, that the curve for primary memory shows a rising tendency with favorable influences from October to January, a period of depression for January, February, and the first part of March, and a rising tendency with favorable influences from March to June.

#### 4. COMPARISONS OF MENTAL AND PHYSICAL SEASONAL PERIODICITY.

If we compare the results from the mental and physical tests in the two accounts just given, they show certain striking similarities. They all show a sharp rise at the beginning, a regular improvement until January, a period of depression from the middle of January to the first of March, and a regular rise to the ends of the tests. While there are a few differences, the general tendencies outweigh them. The larger changes in muscle strength are undoubtedly due to a large extent to physical growth and practice effects. In Tables IX and X, we find that the greatest increase in physical strength was in boys from 15 to 17 years old. We also see that the increase for nine months for those who took the tests five times per week was for all ages nearly double the increase made by those who took the tests but once per week. It would seem, therefore, that about one-half of the improvement of the B. division was the effect of the extra practice received by that group.

We also have the interesting phenomena that at all ages except at 16-17, the gain with the left hand was greater than with the right, in one case being three times as great. The average gains with the right and left hands for those who took the tests five times weekly was 12.7 Kg. and 14.5 Kg., respectively, while that for those tested but once per week was 6.2 Kg. and 7.2 Kg., respectively, for the same time. In no case was a continuous gain made during each of the nine months except in the case of one boy 15-16 years old in the B. division.

In the Mental Tests the effects of practice and growth are very small. In no case in either group was a continuous monthly gain made throughout the year. With the exception of five individuals, every boy had made his highest record of the entire series of tests by the first of January. The highest records in the entire set of tests were made by five individuals, two of the very bright boys between the ages of 13 and 14 years, and three older boys, one 17, one 18, and one 19 years old, each of whom had been out of school and working during the two or three years just preceding.

The Dynamometric tests for variations in physical abilities seem to be an excellent means for judging the growth and development of physical strength. The same validity, however, cannot be claimed for the mental tests used in this investigation. Records made by individuals from day to day were very erratic, and often seemed to be without any apparent causes in spite of all precautions to make the material and procedure uniform from day to day.

The abilities of this group in primary memory were practically fixed before the tests began, and in only a few cases were any large practice effects noticeable. One of the greatest difficulties in mental tests is that many boys become confused when engaged in taking them. Among the ten boys in the B. division who took the tests daily, five could usually be depended upon to make good scores. The other

five were very nervous and easily became confused, making often very low records. I have taken the individual records of each boy, and by comparing them with the records of temperature, humidity, etc., sought to discover causes. In most cases the results of such comparisons are contradictory or baffling. But this is a condition that every one who gives mental tests must expect to meet, and in order to meet it, the investigators depend on statistics.

Every science grows by improvement in its methods, and while the method used in the mental tests is far from perfect, it is about as reliable as any yet devised. The memory results are valuable because this is one of the most exhaustive tests ever made, and they are doubly valuable for purposes of comparison with the records of the physical tests, given to the same groups at the same time each day for so long a period. So far as I have been able to discover, it is the only investigation which combines the results of mental and physical tests on a homogeneous group for so long a time.

A comparison of the tables shows quite conclusively that the same set of causes operate, to a certain extent at least, in controlling both mental and physical abilities through a relationship as yet unknown in detail. This is especially seen in the period of depression in January and February, a period which all investigators have found, though the exact time it occurs differs in individuals, and in all probability differs under varying weather conditions. The school building where the boys spent their time was almost ideal as to light, space, ventilation, temperature, and humidity, and these favorable surroundings tended to cause both mental and physical energy to grow beyond the time where a pause usually takes place.

The individual records show that the period of depression in muscle strength begins anywhere between the middle of December and the middle of January, and lasts from 3 to 10 weeks. In some subjects its effects are overcome by the

middle of February, in others it lasts until sometime in March, and in one case of a 17-year-old boy, it lasted from February to May. In general the boys of low vitality in the early winter, are the ones who show the depression first. Several boys showed more than one period of depression, but the only period of depression shown by every individual tested was the one which began some time between the middle of December and the middle of January, and lasted from three to ten weeks, varying with individuals.

While the averages for the memory tests show the same general tendencies, the depression tends to appear slightly earlier in some cases and slightly later in others. The records from day to day vary so much, due to accidental causes, that it is sometimes difficult to see the depressions in the weekly averages, but the individual monthly averages bring out the depression referred to in the preceeding sentence in almost every individual tested.

These results tend to confirm the results of Kuhnes and Lehman and Pedersen on one hand, and those of Schuyten and Lehman and Pedersen on the other. They show that in periodicity, the time and extent of the period of depression about the beginning of the year is different for adults and for youths. They also tend to clear up the conflicting results of other investigators who found periods of depression all the way from November to March, by showing that these are simply individual variations of a more or less universal phenomenon.

They tend to dispute the idea that physical and mental abilities go by contraries as do growth in height and weight. Finally, they give added validity to the idea of a seasonal growth rhythm, a cosmic rhythm, which, allowing for various individual differences in adaptation, affects all individuals profoundly, and is manifested in a multitude of ways in human life.

TABLE VIII, B DIVISION

WEEKLY AVERAGES

		Avg. mid-Sun		Hu- % Char.	Hour	R	L	M	4's	5's	6's	
Mo.	Tem.	ity	shine	of day								
Oct.	10	58	93	100	Cl	2 P. M.	43	40	10.3	4	3.1	3.2
	11	64	91	60	Cl	10 A.	43.3	39.5	8.3	3.3	2.5	2.5
	12	67	91	77	Cl	11 A.	46.1	41	8.2	3.1	2.8	2.3
	13	68	57	58	Pc	1 P.	46.2	42.9	11	3.7	4.1	3.2
	14	70	69	60	Pc.	1 P.	44.7	42.4	10.5	4	3.5	3
	17	74	53	87	Cl	2. P.	44.9	42	8.8	3.3	3.1	2.4
	18	74	82	100	Cl	11 A.	46.2	41.3	9	2.8	3.2	3
	19	65	80	76	Cl	1 P.	45.9	43.3	9.4	3.4	3.5	2.5
	20	47	86	0	C	9 A.	43.7	42.3	9.8	3.4	3.4	3
	21	44	94	0	C	1 P.	42.6	43	9.4	3.5	3.1	3.5
	24	60	51	69	Cl	9 A.	45.5	42.4	10	3.7	2.9	3.4
	25	58	24	81	Cl	1 P.	50.5	44.3	9.3	3.2	3.4	2.7
	26	67	64	90	Cl	9 A.	47.2	45.3	9.5	2.5	3.8	3.2
	27	46	36	56	Pc	1 P.	47.7	43.9	9	3.8	2.3	2.9
	28	34	55	0	C	1 P.	49.6	42.5	8.8	3.5	2.6	2.7
	31	59	44	75	Cl	10 A.	49.6	44	11.7	3.8	4.3	3.6
	1	54	68	12	C	1 P.	48.7	47.4	10.5	3.6	3.3	3.6
	2	40	63	79	Cl	9 A.	47.9	43.5	10.3	3.9	3.3	3.1
	3	36	56	100	Cl	9 A.	47.8	44.2	9.7	3.2	3.3	3.2
	4	38	63	0	C	9 A.	46.6	43.7	10.8	4	3.5	3.3
	7	54	65	100	Cl	9 A.	49.2	45.9	10.1	3.5	3.7	2.9
	8	51	80	87	Cl	10 A.	48.1	45.5	11.6	3.9	4.2	3.5
	9	60	73	91	Cl	9 A.	50.1	46.3	10.9	3.8	3	4.1
	10	40	87	59	Pc	9 A.	49.6	44.8	9.9	3.8	3.2	2.9
	11	36	77	98	Cl	9 A.	49	46.6	10	3.8	3.1	3.1
	14	40	54	49	C	2 P.	51.2	46.1	11	3.3	3.3	4.4
	15	34	69	0	C	2 P.	49.3	44.7	11.3	3.8	3.8	3.7
	16	34	85	46	Pc	2 P.	50.7	47.5	10.7	4	3.1	3.6
	17	33	70	0	C	2 P.	50.5	47.3	10.9	3.6	3.6	3.7
	18	40	60	20	C	2 P.	49	47.9	9.5	3.5	2.9	3.1
	21	44	72	7	Pc	2 P.	50.1	48.4	10.2	3.3	3.3	3.6
	22	40	87	100	Cl	1 P.	50	47.9	11.6	3.9	3.8	3.9
	23	52	61	100	Cl	11 A.	51.4	49.4	9.2	3.7	2.8	2.7
	24					Thanksgiving Day						
	25	49	49	82	Cl	2 P.	51.2	48.1	10.4	3.7	3.3	3.4
	28	32	72	95	Cl	2 P.	52.6	48.6	8.9	3.6	2.8	2.5
	29	32	84	8	Pc	2 P.	51.8	48.1	10.7	3.8	3.5	3.4
	30	26	59	100	Cl	11 A.	52.2	49.4	10.9	3.8	3.3	3.8
	1	23	64	0	C	2 P.	53	49.4	9.9	3	3.4	3.5
	2	26	52	23	C	2 P.	52	50.1	11	3.9	3.1	4
Dec.	5	30	61	0	C	2 P.	52.1	49.5	10.7	3.5	3.8	3.4
	6	26	49	0	C	1 P.	53.5	49.3	10.9	3.8	4	3.1
	7	28	60	76	Cl	2 P.	50.3	48.7	10.2	3.3	3	3.9
	8	30	50	39	Cl	1 P.	52.1	49.4	9.2	3.4	2.7	3.1
	9	34	64	4	C	2 P.	51.3	48.5	10.8	3.6	3.4	3.8
	12	38	68	10	C	2 P.	52.2	49.3	10.7	3.8	3.5	3.4
	13	38	68	10	C	2 P.	52.2	49.3	10.7	3.8	3.5	3.4
	16	41	71	13	C	2 P.	52.5	49.6	10.8	3.9	3.6	3.5
	17	41	71	13	C	2 P.	52.5	49.6	10.8	3.9	3.6	3.5

TABLE VIII, B DIVISION

WEEKLY AVERAGES

HUMIDITY, WIND, & WAVE TABLES												
Avg. mid-Sun of												
Mo.	Tem.	ity	shine	Char. day	Hour	R	L	M	4's	5's	6's	
12	21	52	33	Pc	2 P.	54.9	53.6	11.1	4	3.2	3.9	
13	21	50	70	Cl	2 P.	52.4	46.7	11	3.6	3.7	3.7	
14	34	30	100	Cl	2 P.	51.7	49.2	11.2	3.3	3.7	4.2	
15	38	51	84	Cl	2 P.	51.4	49.6	9.7	3.9	2.8	3	
16	36	58	100	Cl	2 P.	52.3	47.7	10.3	3.8	3.2	3.3	
19	39	48	38	C	2 P.	53.4	48.9	11.6	3.6	3.7	4.3	
20	28	69	79	Cl	10 A.	54.3	49.9	11.2	3.6	3.6	4	
21	30	59	69	Cl	1 P.	52.8	49.8	11.1	3.5	4.6	3	
22	36	95	0	C	2 P.	52.9	50.3	11.5	3.8	3.9	3.8	
23	30	62	66	Cl	1 P.	55.3	51	11.9	4	4.2	3.7	
Jan.	9	32	47	83	Cl	2 P.	53.6	51.2	12.1	3.6	3.9	4.6
10	46	69	92	Pc	2 P.	53.8	52.1	10	3.6	3	3.4	
11	51	81	38	C	2 P.	54	51.2	9.9	3.5	3.5	2.9	
12	30	83	0	C	2 P.	54.5	50.5	10.3	3.7	3.6	3	
13	36	100	0	C	2 P.	53.8	50.9	10.5	3.7	3.6	3.2	
16	25	72	0	C	2 P.	53.9	52.4	10.4	3.8	3.6	3	
17	27	100	0	C	2 P.	55.5	51	10.6	3.7	3.4	3.5	
18	26	93	0	C	2 P.	55	52.5	11.4	3.8	3.7	3.9	
19	37	96	85	Cl	2 P.	55	50.2	10.5	3.5	3.5	3.5	
20	44	87	6	C	2 P.	55.8	52.2	11.6	3.3	3.6	4.7	
23	34	61	68	Pc	2 P.	52.9	49	9.8	3.8	3.1	2.9	
24	40	60	49	C	2 P.	54.5	51.7	10.4	4	2.5	3.9	
25	47	88	0	C	2 P.	54.9	52.4	10.9	4	3.5	3.4	
26	58	76	44	C	2 P.	53.9	51.5	10.5	3.9	3.6	3	
27	49	84	9	C	2 P.	55.9	52.2	10.8	4	3.9	2.9	
30	34	55	76	Cl	2 P.	53.3	50.7	10.7	4	2.9	3.8	
31	48	66	73	Pc	2 P.	53.8	50.9	10.2	3.9	3.2	3.1	
Feb.	1	64	44	100	Cl	2 P.	54.6	49.9	11.2	3.8	3.5	3.9
2	36	73	100	Cl	2 P.	53.9	50.5	10.8	3.2	3.2	4.4	
3	36	81	16	C	2 P.	53.9	50.5	11	4	3.5	3.5	
6	35	89	0	C	2 P.	54.1	49.8	10	3.1	3.2	3.7	
7	34	82	2	C	2 P.	53.5	49.9	10.2	3.4	3.2	3.6	
8	33	67	73	Pc	2 P.	54.1	51.3	10.2	3.2	3.5	3.5	
9	35	78	100	Cl	2 P.	54.3	50.4	9.8	3.3	3.1	3.4	
10	30	64	100	Cl	2 P.	54.4	51.8	10.1	3.6	3.4	3.1	
13	48	90	38	C	2 P.	53.5	50.8	9.5	3.4	3.3	2.8	
14	50	67	54	Ps	2 P.	54.7	49.9	9.5	3.1	2.7	3.7	
15	54	48	100	Cl	2 P.	55.3	51	9.6	3.6	3.5	2.5	
16	66	77	45	Pc	2 P.	55.3	52.5	10.7	3.7	3.7	3.3	
17	60	82	89	Cl	2 P.	54.9	52.3	9.7	3.4	3.3	3	
20	23	76	42	Pc	2 P.	54.5	51.5	10	4	3.1	2.9	
21	20	83	75	Pc	2 P.	54.7	51.5	9.8	3.9	2.5	3.4	
22	Washington's Birthday											
23	30	89	61	Cl	2 P.	53.3	52.3	10.8	4	3.6	3.2	
24	36	80	100	Cl	2 P.	53.7	53.1	9.2	3.1	3.1	3	

TABLE VIII, B DIVISION						WEEKLY AVERAGES						
	Mo.	Tem.	Avg. mid-Sun of ity shine day		Char.	Hour	R	L	M	4's	5's	6's
Mch.	27	34	77	100	Cl	2 P.	53.9	51.2	9.8	3.5	3.3	3
	28	28	100	0	C	2 P.	53.3	51.4	10.1	3.4	3.6	3.1
	1	30	75	25	C	2 P.	52.5	51.4	10.3	3.1	3.2	3.3
	2	36	84	100	Cl	2 P.	53	51.3	10.2	3.4	3.2	3.6
	3	49	68	100	Cl	2 P.	55	52.8	10.1	3.9	3	3.2
	6	52	74	32	Pc	2 P.	54.4	51.9	10.2	3.8	3.1	3.3
	7	43	79	0	C	2 P.	54.3	52.7	10.9	3.6	3	4.3
	8	48	59	66	Cl	2 P.	55	52.5	9.2	4	2.4	2.8
	9	60	59	79	Cl	2 P.	55.1	52.3	9.8	3.7	2.9	3.2
	10	56	42	52	Pc	2 P.	54.9	52.9	11	3.7	3.3	4
	13	40	48	90	Cl	2 P.	54.3	52.3	11	3.9	3.6	3.5
	14	46	31	97	Cl	2 P.	54.4	52.5	10.8	3.9	3.4	3.5
	15	36	51	96	Cl	2 P.	54.5	53	10.5	3.4	2.8	4.3
	16	30	36	85	Pc	2 P.	55.7	54.1	10.6	3.9	3.3	3.4
	17	50	97	39	Pc	2 P.	55.1	52.9	9.1	3	3.7	2.4
	20	59	27	100	Cl	2 P.	56.3	53.3	10.4	3.7	3.1	3.6
	21	64	32	84	Cl	2 P.	54.3	53.5	11.8	4	3.8	4
	22	54	28	67	C	2 P.	54.9	53.5	10.9	3.8	2.9	4.2
	23	42	39	100	Cl	2 P.	55.4	52.9	12	3.9	3.9	4.2
	24	43	32	100	Cl	2 P.	53.8	51.4	10.7	3.7	3.3	3.7
	27	41	42	90	Cl	2 P.	55.5	52.8	11.6	4	3.9	3.7
	28	50	36	81	Cl	2 P.	55.3	53.4	10.1	3.3	2.8	4
	29	45	84	58	Pc	2 P.	55.8	53.5	10	3.8	3	3.2
	30	37	45	59	Pc	2 P.	54.9	54	9.7	3	3.1	3.6
Apr.	31	38	52	6	Cl	2 P.	55.2	52.7	11.0	3.8	3.8	3.4
	3	44	91	4	Cl	2 P.	54.6	53.8	11.5	3.8	3.6	4.1
	4	58	81	30	Cl	2 P.	54.6	54.6	12.2	3.6	3.9	4.7
	5	48	63	29	Cl	2 P.	56.2	53.2	10.5	3.5	3	4
	6	58	77	47	Cl	2 P.	56.1	54.8	11.2	4	4	3.2
	7	39	50	29	Cl	2 P.	56.2	53.2	10.9	4	3.4	3.5
	10	50	44	75	Pc	2 P.	55.7	55.1	11.8	3.8	4.3	3.7
	11	52	93	0	C	2 P.	56.7	53.9	9.8	2.9	3	3.9
	12	60	61	63	Pc	2 P.	55.8	53.6	11.1	3.7	3.2	4.2
	13	60	94	34	C	2 P.	55.9	54	11.5	3.9	3.6	4
	14	49	44	73	Cl	2 P.	55.9	54	11.5	3.8	3.5	4.2
	17	64	30	84	Cl	2 P.	54.4	52.2	11.7	3.6	3.9	4.2
	18	59	86	7	C	2 P.	57.8	55.3	10.0	3.3	3	3.7
	19	58	60	61	Pc	2 P.	57.8	54.5	9.7	3.3	3	3.4
	20	60	50	50	Pc	2 P.	56.8	54.1	10.7	3.5	3.4	3.8
	21	60	37	74	Cl	2 P.	56	54.1	10.3	3.4	3.2	3.7
	24	50	43	99	Cl	2 P.	56.3	53.5	10.4	3.7	3.1	3.6
	25	54	38	100	Cl	2 P.	56.4	55	12.7	4	3.7	5
	26	62	36	67	Pc	2 P.	56.4	55.8	11.7	4	2.7	5
	27	56	83	0	C	2 P.	58.9	55.8	10.2	3.7	3	3.5
28	64	66	31	Pc	2 P.	57	54.8	11.2	3.8	3.1	4.3	

TABLE VIII, B DIVISION						WEEKLY AVERAGES						
Mo.	Avg. Tem.	mid-ity	% shine	Char. of day	Humid.	R	L	M	4's	5's	6's	
May	1	51	96	3	C	2 P.	57	54.3	12.3	4	3.9	4.4
	2	48	42	100	Cl	2 P.	57.7	53.7	11.9	3.4	3.9	4.6
	3	49	40	7	C	2 P.	58.9	57.3	10.8	4	3.5	3.3
	4	54	35	100	Cl	2P.	59.2	54.3	11.2	3.9	3.4	4.9
	5	55	32	100	Cl	2 P.	58.7	55.8	11.5	3.7	3.7	4.1
	8	71	50	100	Cl	2 P.	57.1	55.4	10.9	3.9	3.1	3.9
	9	78	35	99	Cl	2P.	59.0	55.9	11.7	3.3	4.4	3.9
	10	76	47	100	Cl	2 P.	58.6	54.6	10.5	3.7	3.8	3
	11	70	36	80	Pc	2 P.	59.7	55.6	11.0	3.8	4.1	3.1
	12	72	27	89	Pc	2 P.	58.6	55.4	11.1	3.7	4	3.4
	15	76	43	92	Cl	2 P.	60.1	56.8	10.8	3.9	3.8	3.1
	16	78	52	78	Cl	2 P.	59.9	54.5	10.6	3.7	3.5	3.4
	17	80	53	100	Cl	2 P.	58.7	53.6	10.5	3.7	3.3	3.5
	18	81	47	90	Cl	2 P.	58.4	55.1	11.6	3.5	3.8	4.3
	19	78	53	100	Cl	2 P.	58.4	54.3	11.5	3.9	4	3.6
	22	71	40	86	Cl	2 P.	58.9	55	11.3	4	4	3.3
	23	70	37	100	Cl	2 P.	59.5	55.4	11.5	3.9	3.8	3.3
	24	78	29	100	Cl	2 P.	59.8	55.6	11.2	3.2	3.9	4.1
	25	82	38	100	Cl	2 P.	58.4	56	11.1	3.5	4.2	3.4
	26	83	41	98	Cl	2 P.	57.8	54.6	11.4	3.6	4.1	3.7
	29	77	53	84	Cl	2 P.	58.6	56.4	10.5	3.5	3.6	3.4
	30	78	67	82	Pc	2 P.	59.6	57.8	11	3.8	4.1	3.1
	31	74	53	78	Cl	2 P.	59	57.7	11.2	3.6	4	3.6
June	1	72	54	87	Pc	2 P.	59.3	57.7	11.3	3.7	3.8	3.8
	2	76	49	82	Pc	2 P.	59.7	57.3	11	3.5	3.9	3.6

Age	No.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	High	Low	Avg.	Gain
14 to 15	R 2 L	38.9 32.4	40.6 37.6	44.2 39.7	46.6 42.4	45.8 41.4	48.6 46.1	50.2 45	51.5 46.3	49 51.5	51.5 51.5	38.9 32.4	46.2 42.5	12.6 19.1
15 to 16	R 1 L	34.9 31.5	36.3 34.1	38.4 37.5	41.9 40.9	43.7 41.9	45.1 43.1	45.7 43.8	47.7 44.1	49.4 47.6	49.4 47.6	34.9 31.5	42.6 40.5	14.5 16.1
16 to 17	R 5 L	49.7 47.4	54.5 51	57.9 54.9	58.8 55.6	57.8 55	58.7 55.9	60.9 57.9	63.7 60	65.1 61.1	65.1 61.1	49.7 47.4	58.6 55.4	15.4 13.7
17 to 18	R 2 L	49.7 45.8	54.5 51.5	57.9 53.6	58.8 55.2	58.6 54.3	55 54	55.9 58.2	59.8 57.5	59.8 60.2	59.8 60.2	49.7 45.8	56.7 54.5	10.1 14.4
Avg.	R 10 L	46.5 42.7	50 46.4	52.9 49.7	54.2 51.4	54.1 51.2	54.6 52.7	56.4 54.3	58.9 55.1	59.2 57.2	59.2 57.2	46.5 42.7	54.1 51.2	12.7 14.5

Age	No.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	High	Low	Avg.	Gain
13 to 14	2 R 2 L	30 25.8	32 27.8	33.3 30	34.3 31.3	33 30.2	34.5 32.5	34.7 32	34.9 32.9	34.5 34.5	34.9 34.5	30 25.8	33.5 30.8	4.9 8.7
14 to 15	6 R 6 L	29.4 26.3	31.4 27.4	32 28.7	32.6 29.9	32.3 29.9	33.3 29.3	34.8 30.2	34.9 31.8	34 32.5	34.9 32.5	29.4 26.3	33 29.6	5.5 6.2
15 to 16	9 R 9 L	39 35.4	40.2 37.5	40.4 38.6	42.9 39.6	42.8 40.1	44 41.9	45.2 43	45.6 42.3	46.9 42.7	46.9 43	39 35.4	43 40.2	7.9 7.6
16 to 17	3 R 3 L	43.9 40.4	44.5 40.6	45.5 41.4	47.4 44.1	46.7 41.6	48.1 41.5	49.8 42.9	51.3 44.8	51.3 45.3	51.3 45.3	43.9 40.0	47.6 42.5	7.4 4.9
19	1 R 1 L	41 35	42 40	41 41	40 42	40 42	40.5 42.8	40.3 42	41.2 46.7	44 48	44 48	40 35	41.9 43.2	4 13
26	1 R 1 L	41 43	43.9 43.7	44 43	43 43	43 43.3	41.8 43	42 44	43 46	42 47	44 47	41 43	32.8 44.2	3 4
Avg. 22	2 R 2 L	36.3 32.7	37.8 34.7	39 35.8	40 37	39.6 36.9	40.8 37	41.3 38.5	42.2 39.1	42.5 39.9	42.5 39.9	36.3 32.7	40 36.8	6.2 7.2

Table X Strength of Grip A Div.

Age	No	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	June	Avg.	High	Low	Greatest Variat'n
14-15	d	9.7	10.	10.	9.9	9.5	9.9	10.8	11.2	11.	10.4	11.2	9.1	2.1
15-16	1	7.	8.2	8.4	7.9	7.6	9.	9.3	12.4	12.8	11.6	12.8	10.2	2.6
16-17	5	8.9	10.8	10.6	10.7	10.6	10.1	10.7	10.9	10.7	10.4	10.9	8.9	2.
17-18	2	10.2	11.7	11.5	11.5	10.7	11.2	12.1	10.8	10.3	8.7	10.8	7.	3.8
Avg.	10	91	10.	10.4	10.6	10.2	10.2	10.8	10.8	10.2	10.1	10.8	9.5	1.3

[illegible]

Table XII Memory Tests A Div.

## CHAPTER IV.

### DIURNAL VARIATIONS IN EFFICIENCY

1. *Introduction.* The question of diurnal variations in mental and physical abilities has received a great deal of attention during the past few years, and since it is involved in the larger question of seasonal periodicity, a brief survey of the progress in this field will be presented and the results of others compared with those of my own original investigations. The results in this field show, with minor differences, a substantial agreement. Several years ago, Lombard<sup>28</sup>, in a series of experiments using his modification of Mosso's Ergograph, found the most favorable periods of the day to be between 10 and 11 a. m. and 10 and 11 p. m., and the poorest between 3 and 4 a. m. and 3 and 4 p. m. He also noted a rise in ability about 2 p. m., which entirely disappeared between 3 and 4 p. m.

Patrice<sup>32</sup>, in testing the strength of himself and one other with Mosso's Ergograph, found 2:30 p. m. to be the best period, the evening to be superior to the morning and to the midnight periods, which were about equal.

Harley<sup>16</sup> gives the following as the results of a six-day Ergographic test:

Hour	9	10	11	12	1	2	3	4	5	6	7	8
K-M	6.2	6.4	8.7	7.0	9.5	8.2	9.9	7.8	8.9	8.7	7.2	8.8

This shows a steady rise till 11 a. m., a slight fall at noon, a rise at 1 p. m., another slight drop at 2 p. m. with a crest at 3 p. m. This is followed by an irregular decline through the rest of the test period.

Kræpelin<sup>20</sup> found a rather unusual variation consisting of a gradually increasing efficiency during the three or four hours after each meal. He explains this decrease of muscular

ability as the result of the increased demands on the blood supply during the process of digestion. At least one German investigator, Røemer, has reported similar variations.

Christopher<sup>6</sup>, in a series of 90 second Ergographic tests, on 1127 Chicago school children at each hour of the day, together with more extended tests with four boys and four girls, finds a maximum at 9 a. m., a slight decrease till 11:30 a. m., where there is a heavy loss, and this is followed by a renewal of energy at 1 p. m., increasing to the highest point at 2:30 p. m., whence it descends till 4 p. m. His results show (1) that there is a much greater drop in efficiency during the morning period than in the afternoon, and that (2) strength is not so great in the afternoon as in the morning, but it is better sustained.

## 2. DAILY VARIATIONS IN VOLUNTARY MUSCLE CONTRACTIONS. (STOREY)<sup>37</sup>

(1) *Method.* During the year 1899, Storey, then at Stanford University, tested a number of individuals at irregular intervals, as to the daily variations in the power of voluntary muscular contraction. In the first tests, Lombard's modifications of Mosso's Ergograph was used. Later he used the Upham Dynamometer.

(2) *Results.* He found a rise in power each morning till 10 or 11 a. m., a fall till 1 p. m., a rise till 4 p. m., and a fall till 6 p. m. The morning maximum comes near 11 a. m. and the afternoon maximum comes near 4 p. m.

(3) *Conclusions.* The following is a summary of his more important conclusions:

- 1—Mental or muscular work producing partial fatigue, i. e., not exhaustion, reduces the power of voluntary muscular contraction.
- 2—Sleep and food restore ability to work.
- 3—The power of voluntary muscular contraction is directly influenced by bodily health.

- 4—Exercise has an immediate and stimulating effect on the power of muscular contraction.
- 5—Ordinary variations in temperature have no perceptible effect.

(4) *Criticism.* This was a pioneer in the field, and like all pioneer investigations, the method and procedure are, perhaps, not so carefully controlled as they might be. Many details are lacking in the report, and the details are poorly presented. As a pioneer work, his investigations are worthy of mention.

### 3. THE DIURNAL COURSE OF EFFICIENCY. (MARSH)<sup>30</sup>

(1) *Description.* In 1906, Marsh began a series of experiments at Columbia University dealing with the daily variations in mental, physical, and psycho-physical efficiency. His work attempted to find out whether there are normally recurring variations in ability during the day. Several groups of subjects were investigated for one or two days, and a few subjects for several days, among them seven graduate students, sixteen female undergraduate students, twenty-two factory operatives and himself. In these tests he not only tried to find out what was shown in the laboratory by students, but also just what people accomplish under ordinary conditions of life. As a rule, the tests were given four times daily, before breakfast, lunch, dinner, and bedtime.

(2) *Results.* The results from his different tests will be presented separately according to the kind of test used.

(a) *Speed and Accuracy of Movement.* In this test, which consisted of striking squares with a pencil point, an inverse ratio of speed and accuracy is shown, the most accurate tests being from 9 to 11 a. m., while the best speed was from 12 m. to 2 p. m.

(b) *Accuracy.* In this test, which consisted of snapping a wooden disc at an opening 60 cm. distant, the

most accurate results were made from 12 m. to 2 p. m., and the least accurate were made from 4 to 6 p. m.

(c) Speed. In this test for writing several words, the results show the best speed from 12 m. to 2 p. m., and the poorest from 4 to 6 p. m.

(d) Tapping. These tests show a maximum rate from 9 to 10 p. m., with the greatest accuracy about the middle of the day.

(e) Dynamometric Grip Tests. These were taken by Marsh for 30 days with great regularity of external and subjective conditions, using the Collins Dynamometer. The average of grips taken with the right hand is shown in the table.

7:00	8:30	10	11:30	1:30	3	4:30	6	7:30	9	10:30	11-12
60.6	63	64.3	66.2	65.5	66.2	66.7	69	65.4	66	62.8	60.7

The results show a rise to 11:30 a. m., a slight drop at 1:30 p. m., a second rise with a crest at 6 p. m., followed by a decrease to 11 p. m.

(f) Work in Factories. In these tests, women factory operatives show a low morning power which increases till 11 a. m., falls slightly till 1 p. m., increases to a maximum between 3 and 5:30 p. m., and falls till bedtime.

(g) Discrimination. In the tests for discrimination, the best ability was found at noon, and the poorest at the extreme periods. The shortest time was from 12 m to 2 p. m., while the poorest was from 9 to 11 p. m.

(h) Mental Tests. Mental tests were made in association, memory, and addition, all of which showed that from 12 m. to 2 p. m. was the most favorable, and 9 to 11 p. m., the least favorable.

(3) *Conclusions.* For physical abilities including work in factories, there seems to be a gradual increase from the early morning hours in tests till 6 p. m., and in work till

about 3 to 5 p. m., followed by a decrease in both cases to 11 p. m.

For mental abilities, the tests show a midday maximum of accuracy. The morning is favored though but slightly. In the strictly mental but more complex activities there is a similar inclination to the morning period both in rate and accuracy.

(4) *Criticism.* In this work, the author employed a great variety of means in testing mental and physical efficiency. While the physical tests are quite well worked out, the data are rather weak on the mental side. The chief criticism is that the author drew his conclusions from too small an amount of data. His work should have been more extended, and more daily records should have been made each day to give his conclusions the degree of validity assumed. However, the author used the methods which were considered best at the time, in making his tests, and there has been but little improvement in the methods since his work, so that it still remains the standard work on the diurnal course of mental and physical efficiency.

#### 4. DIURNAL VARIATIONS AND EXERCISE EFFECTS. (LEHMAN AND PEDERSEN)<sup>25</sup>

(1) *Diurnal Variations.* Lehman made tests to discover diurnal variations during a period of four days, and his results are shown in the following table:

9 A. M. (after breakfast)	32.5 Kilos
1 P. M. (before a 2-hour walk)	31.8 "
3 P. M. (after a 2-hour walk)	35.3 "
11 P. M. (before retiring)	30.9 "

(2) *Exercise.* Pedersen made a similar series of tests, taking a walk of from 2 to 4 hours duration at different times of day with the following results:

	On level ground	On rising ground
Record made before walk	37.2 Kilos	36.8 Kilos
Half way	37.8 “	
Top of rising ground		37.9 “
Record made on return	38.0 “	38.4 “

The first of these shows the influence of the time of day, while both show the beneficial effects of the two hours' walk. They also show that only those tests taken in the morning before work are rigidly comparable, as the kind of work done during the day has its effects on the results. The greater increase in muscle strength on the high ground, shows the beneficial effects of lowering the atmospheric pressure.

## 5. DIURNAL VARIATIONS IN MUSCULAR ENERGY. (KUHNES)<sup>21</sup>

(1) *Description.* Kuhnes, whose work I have already reported under “Seasonal Periodicity,” made a thorough investigation of diurnal periodicity as shown in muscle strength. Each day, for 505 consecutive days, he took three tests with each hand in three different positions, alternately with the right and left hand, seven times daily, making in all twenty-one tests with each hand each day. The tests were very carefully controlled, and in order to eliminate the effects of holding the dynamometer in different positions, the three positions were always the same and taken in the same order, viz.—(1) each hand hanging down, (2) each hand held vertically, and (3) each hand held horizontally.

(2) *Results.* The results cover about 26,500 measurements, and the averages are somewhat as follows: At 7 a. m. comes a relatively low measurement followed by a rapid rise at 9 a. m., a slight drop at 12 m., a small rise at 2 p. m., which is the best time of all, a small drop at 6 p. m., a slight rise at 8 p. m. and a decided drop at 11 p. m. The average results for each hour during the whole period is shown in the accompanying table.

	7 a.m.	9 a.m.	12 m.	2 p.m.	6 p.m.	8 p.m.	11 p.m.
Average	43.5	46.5	46.5	46.8	46.5	46.7	45.3
Maximum	49	50.6	52.0	50.8	50.8	51.1	50.6
Minimum	38.5	39	36	41.5	40.8	43.0	40.6
Diff. of Max. and Minimum	10.5	11.6	14	9.3	10	8.1	10
Median	43.6	46.8	46.7	47.1	46.9	47.3	45.9
Mean Variant.	1.5	1.7	1.8	1.7	1.7	1.8	1.8

(3) *Conclusions.* There is a distinct diurnal course of efficiency which starts low, rises till 12 m., drops slightly, but rises again showing its crest at 2 p. m. In the afternoon there is a drop at 6 p. m., a small rise at 8 p. m., followed by a rapid decrease till 11 p. m. The average curve here described is also the curve of 68 per cent. of the 505 days.

From the valuable introspections which he kept each day, he concludes that physical fatigue or physical inactivity cause a marked decrease in physical strength, while mental fatigue has an influence that differs from that shown by physical fatigue.

(4) *Criticism.* This work has been criticised before, but I will add here that it is the most complete record of diurnal efficiency covering a long period of time, which has ever been made. All the data are given in complete form, and a most careful search fails to show any errors in the method, or in the interpretation of the results.

#### 6. VARIATIONS IN EFFICIENCY DURING THE DAY. (GATES)<sup>11</sup>

(1) *Method.* During the year 1913-4, while a student at the University of California, Gates attempted to discover diurnal rhythms of efficiency by a variety of mental and physical tests. The subjects were pupils of the fifth and sixth grades in the public schools. During the five days of the tests, each class was divided into five groups of about eight pupils each. Each group was tested separately at 9 a. m., 10 a. m., 11 a. m., 1 p. m. and 2 p. m. On each succeeding test day, each group except that tested last was tested one hour later than before, while the one previously

tested last, was tested first. In this way each group was tested at a different hour each test day, and once at each of the hours mentioned above.

(2) *Results.* The table here given show the combined record for all six classes in per cent., the first record being used as a base.

Hours	9-10	10-11	11-12	1-2	2-3
Addition tests	100	102.4	104.2	102.3	103
Multiplication tests	100	101.9	105.1	100.9	103
Auditory Memory	100	105.9	106.7	99.4	102.4
Visual Memory	100	103.2	109.2	99.06	103.4
Recognition tests	100	104.7	105.9	100	103.7
Maze Test—speed	100	100.34	100.93	108.9	112.2
Maze Test accuracy	100	102.9	104.2	98.2	96
Completion tests	100	105	109.7	106.2	108.8
Cancellation tests	100	101.8	104.4	194.9	105.5

Summarizing the results we find that in the addition, multiplication, memory, recognition, and completion tests there is a more or less steady rise in efficiency from 9 a. m. to noon, followed by a decrease of differing but always noticeable extent at 1 p. m. and a subsequent rise during the last hour.

In the speed and accuracy tests, and in the cancellation test, there is a steady rise through the day with a maximum at the end. Speed is greater, but accuracy less in the afternoon, therefore it would seem that speed is attained at the expense of accuracy.

All of the functions tested show improvement due to practice effects, varying from 7 to 33.3 per cent. There are no sex differences, or effects of fatigue, temperature changes, humidity, or weather in general shown in this study. The author finds high correlations only in the two arithmetical and in the two memory tests, while in the others, the correlations except in related functions do not amount to much, and that in such dissimilar tests the correlation results are largely a matter of accidents.

He concludes that the strictly mental activities are more affected by fatigue than are the motor activities or those which involve muscle strength, the first showing a maximum in the late afternoon while motor functions show a continuous increase throughout the whole school day.

(3) *Criticism.* The account of this investigation is well written and the author shows a broad and comprehensive knowledge of the work of other investigators in similar and related fields. In the tests used, in nearly every case the time given was far too short for all the children to perform the tasks demanded, so that after the children found out they could not do all of any test within the time limit, haste was probably a prolific source of error. It seems also that while the tests covered a great variety of functions, they were too few in number to warrant any universal conclusions, and it is to be regretted that preliminary and verifying tests were not made. However the author recognizes the limitations of his results, and does not draw any fanciful conclusions which are unjustified by the results. The range of the tests and the care with which they were given, gives much validity to the results, which agree closely with those of other American investigators in this field. It is easily the best of its kind, and it must be taken into account by all future investigators of diurnal variations in mental abilities.

## 7. DIURNAL VARIATIONS IN MEMORY AND ASSOCIATION. (GATES)<sup>12</sup>

(1) *Method.* Gates supplemented his first investigation by a series of memory and association tests made on groups of from six to fourteen college students, numbering 165 in all. The tests were made at each hour of the day from 8 a. m. to 5 p. m., excepting only the noon hour. Before taking the tests each student was asked to state, among other things, the time of day when he felt he could do his most and best work. Tests were given in auditory memory,

visual memory, substitution, recognition, and logical memory (Healy Test).

(2) *Results.* The average results in per cent for each of the various tests is here given.

Hour	8	9	10	11	1	2	3	4	5
Auditory memory	100	97.5	98.8	103.3	97.4	94.5	98.2	95.5	93.8
Visual memory	100	99.3	101.5	101.5	98.0	100.1	101.7	102	100
Substitution	100	102.7	195.2	104.3	96.0	102.6	101.5	101.2	94.3
Recognition	100	115.7	122.2	115.7	106.5	111	120	120	116.5
Logical memory	100	109	107.7	103	95.5	99.3	101.4	102.2	91.3
Avg. of all tests	100	104.3	106.6	105.6	98.7	100.6	105.1	104.2	100.4

The results from all these tests show a great similarity. Beginning at 8 a. m., all the curves rise till 10 and some till 11 a. m. The 1 p. m. figure is quite low in all tests and always lower than the late afternoon.

(3) *Conclusions.* In the subject's own estimates of their best hour, many choose too early an hour, few choose 10 a. m. or 11 a. m., and practically none choose the late afternoon hours. From this Gates draws the conclusion that one's subjective feelings with regard to the time of greatest efficiency, are not reliable. The hours of greatest efficiency are those at which fatigue (it would seem), should be very great. A man should, therefore, by practice in the voluntary disregard of the mere feelings of fatigue learn the limits of his ability and thus attain greater efficiency.

(4) *Criticism.* In this series of tests the author used several well known methods for testing efficiency in the field of immediate memory and association. The investigation is valuable chiefly from the fact that such a large group (165 college students) were given such a variety of tests for purposes of comparison. It is to be regretted, however, that the experiments lasted only three days, and that on the days mentioned, the subjects spent the time in continuously taking tests. The questionnaire submitted to each student before taking the tests, brought out some very interesting facts, and

shows one's own opinion of his best working hours is not reliable.

#### 8. SUMMARY OF PROBLEMS AND RESULTS IN DIURNAL PERIODICITY.

The diurnal course of efficiency seems to be pretty well established both for mental and physical abilities. In both cases, all previous investigators have found both a morning and an afternoon crest. The records for variations in physical abilities, including work stories, show a continuous increase in the morning till about 11 a. m., a slight drop from 12 m. to 1 p. m., with a further rise to a maximum sometime between 3 and 6 p. m. The results for mental work show a more or less steady rise till 11 a. m., a slight drop around noon with a new high level around 2 p. m., then a gradual decrease till the close of the day. Kuhnes found that in many cases physical strength grows continuously till about 8 p. m., after which it declines. This fact was also noted in some factory workers by Marsh.

In Speed and Accuracy Tests, accuracy is better in the morning and speed greater in the afternoon, a result which seems to show that speed is often gained at the expense of accuracy.

Kuhnes found in a test covering 505 consecutive days that the average daily curve in dynamometric tests is also the curve for 68 per cent. of the days. This would seem to indicate the great importance of diurnal variations in any study of seasonal periodicity.

#### 9. DIURNAL PERIODICITY IN MY ORIGINAL EXPERIMENTAL INVESTIGATION.

In my own investigation, through October, November and December, the B. division was tested at various hours from 9 a. m. to 3 p. m. After January the tests were always given between 2 p. m. and 3 p. m. The following table shows the distribution of variations 1 Kg. from the weekly average in grip strength.

Hour of the Day	9 to 10	10 to 11	11 to 12	1 to 2	2 to 3
Per cent. of tests given at each hour	20	8	8	24	40
Per cent. of test varying 1 Kg. from the average	12	12	12	30	30
1 Kg. above the average	5	10	15	35	35
1 Kg. below the average	30	20	10	20	20
Rank	5	4	3	1	2

These data seem to show a diurnal course of efficiency which rises continuously from 9 a. m. to 3 p. m. for muscle energy. The exceptionally low records made at 10 to 11 a. m. and at 1 to 2 p. m. were made during the first week. There was no test made at 9 a. m. until Monday of the third week, so we find these low records at the other hours. In spite of this fact, however, the average of the 9 a. m. records is the lowest of all the hours shown as can be seen in the following table:

RIGHT HAND						LEFT HAND					
Hour	9-10	10-11	11-12	1-2	2-3	Hour	9-10	10-11	11-12	1-2	2-3
Avg.	47.7	48.8	48.9	49.3	51.2	Avg.	44.5	44.7	45	46	46.3
High	50.1	54.3	54.4	55.3	57.1	High	46.6	49.9	50.4	51	53.6
Low	43.7	43.3	46.1	42.6	43.6	Low	42.3	39.5	41	42.4	40

These results agree with those of other investigators in showing muscle energy increases almost continuously from 9 a. m. to at least 3 p. m.

The results for memory show a similar tendency except for a greater depression from 11 a. m. to 1 p. m., as can be seen from the following table:

MEMORY FOR 15 NUMBERS					
Hour	9-10	10-11	11-12	1-2	2-3
Average	10.1	10.7	10	10.1	10.5
High	10.9	11.7	11.2	11.9	11.6
Low	9.5	8.3	8.2	8.8	8.8

  

MEMORY FOR 4 NUMBERS					
Hour	9-10	10-11	11-12	1-2	2-3
Average	3.56	3.65	3.45	3.64	3.68
High	4	3.9	3.8	4	4
Low	2.5	3.3	2.8	3.2	3.3

## MEMORY FOR 5 NUMBERS

Hour	9-10	10-11	11-12	1-2	2-3
Average	3.32	3.65	3.03	3.47	3.34
High	3.7	4.3	3.3	4.6	3.9
Low	2.9	2.5	2.8	2.6	2.8

## MEMORY FOR 6 NUMBERS

Hour	9-10	10-11	11-12	1-2	2-3
Average	3.2	3.4	2.9	3.1	3.5
High	4.1	4	3.8	3.9	4.3
Low	2.9	2.5	2.3	2.5	3.4

In all probability the results for the series of five numbers are the most reliable. The series of four numbers served as a sort of preliminary test to fix the attention on the task, and to warm subjects up to the work. The series of six numbers was perhaps too long, a perfect score being very rarely made. These results for primary memory all show a rise from 9 to 11 a. m., a drop from 11 a. m. to 1 p. m., a rise from 1 p. m. to 2 p. m. and a slight drop from 2 to 3 p. m. in some cases, while in other the records from 2 to 3 p. m. remain almost stationary. The results from the A. division were almost all made between 2 and 3 p. m., so that they add nothing to the results on diurnal periodicity.

## CHAPTER V.

### OTHER PERIODIC VARIATIONS IN MENTAL, AND PHYSICAL ABILITIES

(1) *Introduction.* Besides the diurnal and seasonal variations, there have been many other suggestions as to periodic variations in mental and physical abilities. Among those we find the so-called Twenty-eight Day period, the Twenty-three Day period, and the Seven Day or weekly period.

(2) *Twenty-eight Day Periodicity.* Malling-Hansen first suggested that vital force was subject to periodic variations every twenty-eight days. Of course there is no doubt about the twenty-eight day periods in females, but the existence of twenty-eight day periods in mental and physical abilities has never been firmly proven or disproven as yet. This is due to the fact that such periods would vary with the individuals and investigators have been much more interested in results from large numbers than from individuals.

Dr. Kuhnes has given this problem more attention than any other investigator. In this investigation in variations in physical ability, he arranged the data in a series of thirteen twenty-eight day periods, counting twenty-eight day periods from the day of his birth. His results when so arranged, show a marked variation through the first three days, an almost constant value from the fourth to the twentieth, and more or less irregularity from the twenty-first to the twenty-eighth day. The highest points are found on the twenty-second, twenty-third, and twenty-fourth days, while the lowest point is found on the third day. Dr. Kuhnes comes to the conclusion from his remarks that they gave little warrant for assuming the existence of a twenty-eight day period in muscle strength.

My own data are not arranged in a suitable form for a comparison with the results of others as to the existence of a twenty-eight day rhythm.

(3) *Twenty-three Day Periodicity.* Stohr describes briefly a Twenty-three Day rhythm found independently by two Germans, Fleiss and Svoboda. Each of these men claim to have found a twenty-three day period in mental and physical abilities on the basis of personal observation, Svoboda claiming that ideas automatically and spontaneously reappear in the mind every twenty-third day.

So far as I know, no American investigator has found similar results. Dr. Kuhnes arranged his data in twenty-three day periods counting from birth. His curve for averages shows a nearly straight trend for 17 days, then rises slightly till the end of the 22 day, and shows a rise of seven kilos on the twenty-third day. This variation is nearly double the rise and fall on any other day. The median curve shows a gradual decline until the tenth day, a sudden drop on the eleventh day, with a gradual rise to the end of the period. The 9 a. m. records show a distinct rise on the twenty-third day, but the point reached is not higher than that on the fourteenth day. He concludes that while there are some unexpected peculiarities in his results for the twenty-third day, his data do not warrant a general acceptance of the twenty-three day period.

In this field, as in the twenty-eighth day period, my own data cannot be arranged in a way that would be comparable with the results of others, or to show any twenty-three day periods.

#### (4) *Weekly Periodicity.*

(1) Introduction. Weekly periodicity has not been investigated to any considerable extent. The fact that for many generations people in many lands have ordered their lives by seven day periods would suggest the possibility of a seven day period in mental and physical abilities.

(2) *Huntington*<sup>19</sup>. Huntington found that on the whole, the curves of work done by piece-workers are higher at the end of the week than at the beginning, Monday being low, and Thursday and Friday the highest, with a falling off on Saturday. He gives the following table for piece-workers in a Cuban factory.

Mon.	Tues.	Wed.	Thur.	Fri.	Sat.
81.9	98.7	99.8	100	98.	97.9

(3) *Kuhnes*.<sup>21</sup> Kuhnes studied the averages of 42 daily tests for fifty-three weeks with the following results:

Days	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
Average	46 Kg.	45.9	46.3	46.1	45.9	46	46.3
Maximum	49.1	49.3	49.5	48.9	48.7	49	48.9
Minimum	42.9	42.0	43.2	43.1	41.5	42.8	43.2
Diff. of M-M	6.2	7.3	6.3	5.8	7.2	6.2	5.7
Mean Var.	1.53	1.66	1.43	1.34	1.31	1.53	1.33
Median	45.5	46.1	46.6	46.3	46.1	45.8	46.3

In this table, Mondays and Thursday show the lowest averages being 4 kg. below the maximum reached on Tuesdays and Saturdays. Kuhnes found that the weekly curve followed very closely that of the days of the most and least study, and that hard study with a lack of exercise caused low records.

## 5. WEEKLY PERIODICITY IN MY ORIGINAL EXPERIMENTAL INVESTIGATION.

In an endeavor to discover any traces of a weekly period in my own results, I first tabulated the daily distribution of the averages 1 Kg. from the averages for the week, and give them in the following table in per cent.

Day	Right Hand		Left Hand		Rank
	Above	Below	Above	Below	
Monday	9	18	6	25	5
Tuesday	12	12	0	16	4
Wednesday	9	0	11	3	2
Thursday	9	0	9	3	1
Friday	19	12	16	11	3

These results show that Monday is the poorest day while Thursday is the best. Monday and Friday are more variable, but on Monday the variations tend to fall below the line of weekly averages, while on Friday they tend to rise above it. The number of such variations on Wednesday and Thursday is small, and almost all of them are above the average for the week.

According to these data, Monday is low, and is followed by an irregular rise through the week to a crest on Thursday. This is followed by a slight drop on Friday. The following tables show the results for the Memory and Grip Tests by days for each month.

GRIP TABLE

Day		Mon.	Tue.	Wed.	Thu.	Fri.
Oct.	R.	45.2	46.6	46.4	45.8	45.6
	L.	42.1	41.7	43.2	43	42.6
Nov.	R.	50.8	49.6	50.4	49.3	48.9
	L.	47.2	46.7	47.2	45.4	46.5
Dec.	R.	53.5	53.4	51.6	52.3	52.7
	L.	50.6	48.6	49.2	49.7	49.7
Jan.	R.	53.4	54.2	54.7	54.5	54.6
	L.	50.8	51.1	51.7	50.8	51.3
Feb.	R.	54	54	54.4	54.2	54.2
	L.	51	50.7	50.7	51.4	51.9
Mch.	R.	54.7	54.6	56.5	56.2	57.3
	L.	52.4	53	52.8	52.9	52.5
Apr.	R.	55.2	56.4	56.5	56.2	57.3
	L.	53.6	54.7	52.6	54.2	54.3
May	R.	58.3	59.1	59.1	58.9	56.3
	L.	53.6	55.4	55.9	55.2	54.9

MEMORY TABLE (15 points)

Oct.	10.2	8.8	9	9.7	9.6
Nov.	10	11.1	10.4	19.1	10.1
Dec.	11.1	11	10.8	10	11
Jan.	10.3	10.3	10.4	10.3	11
Feb.	9.8	9.9	10.3	10.5	10
Mch.	10.9	10.9	10	10.3	19.3
Apr.	11.6	11.6	10.7	11.4	10.6
May	11.4	11.1	11	11.5	11.6

The table for memory does not show any pronounced weekly periodicity for all the months of the year. In October, December, March, and April, the first part of the week seems to be more favorable, but in January, February, and May the reverse is true. In November the middle of the week seems preferable.

The results from the Dynamometric Tests show a similar lack of any weekly periodicity. In November and December, the early part of the week is preferable, but in February and April, the opposite is true. Wednesday is very favorable in October, November, January, and May, while in March there does not seem to be much choice. From the data as presented, therefore, we are not warranted in assuming that there is any weekly periodicity shown either in the mental or physical tests.

## CHAPTER VI. WEATHER INFLUENCES

(1) *Introduction.* Many statements have been made in literature about the effects of various kinds of weather on human thought and action, but very little has been done to test these opinions in a scientific way. Of late, two or three investigators have attempted to discover some existing relations between the variations in the amount of sunshine, temperature, humidity, and air pressure on the one hand, and in the physical, mental, and moral life of the individual on the other. One writer, Huntington, points out the very close relation between various types of civilization and climatic conditions, and concludes that climatic conditions are as important factors in civilization as are the oceans, lakes, rivers, mountains, and natural resources.

While the author does not expect to come to any unusual conclusions in this regard, the results as here shown may give additional proof to facts already well established. The first task, however, will be to give a brief review of the work already done in this field.

(2) *General Weather Effects.*

(a) Conduct and the Weather. (Dexter).<sup>7</sup>

The first American to investigate the effects of the weather to any extent, was Dexter, who tried to study the relations of conduct and the weather. The questionnaire, supplemented by various public and private records on crime, insanity, and school conduct, and the U. S. Government records on weather conditions were used as sources for the data. In each case the relationship established is purely statistical, based on the probability or expectancy of occurrence, all the data being arranged to show the actual distribution of the occurrence, as compared to the expected distribu-

tion of the occurrence. In this study were included data from the records of attendance and discipline in the public schools of New York City and Denver, police records of Assault and Battery, Murder, Insanity, Suicide, and Death; Clerical Errors in a number of New York City banks, and data from laboratory experiments made at Columbia University. These are compared with government records of temperature, humidity, wind, and character of the day.

(1) *Results.* The results, with complete descriptions of the data, tables, and graphs, are described in detail, and from them the following general conclusions are drawn:

1—Males are more influenced by weather conditions than females, and boys are more influenced than girls.

2—Precipitation has little or no effects at all.

3—Barometric changes influence largely through the production of other states of weather, rather than directly.

4—Medium conditions of humidity are more favorable than extremes in either direction.

5—Time of year has no marked effects on conduct.

6—Varying weather conditions affect directly the metabolism of life.

7—Reserve energy is influenced to a marked degree by weather conditions.

8—The quality of emotional states is plainly influenced by the weather.

9—Conduct, death, physical labor, and intellectual activities, bear very different relations to reserve energy.

10—Those weather conditions which are productive of misconduct, in a broad sense of the word, are also productive of health and mental alertness, and

11—Misconduct is the result of an excess of reserve energy not directed to more useful purposes.

(2) *Criticism.* The aim of this investigation was a very worthy and necessary one, and while the method of selecting the data might be improved upon, the author had a vast

amount of materials at his disposal. The chief defect is that only statistical use was made of the data. In this way, the only thing that can be indicated is the statistical comparison between the expected and the actual occurrence of phenomena, all the discussions and conclusions being based on this artificial relationship. What is shown is a probable relationship based on a statistical estimate of the occurrence of phenomena, rather than any actual relationship between the variations in the phenomena. In this way the actual effects of changes in the temperature, humidity, air pressure, as well as those of unusual combinations of atmospheric conditions are almost entirely unnoticed. Then again, the data from the questionnaires, should have received little weight unless the opinions expressed were supported by recorded observations, as many instances have been shown where the opinions of individuals are contrary to the real facts. We should, therefore, exclude that part of the result which is based on such data. In the light of these facts it will not do to give too much weight to his results and conclusions. We must, however, recognize that this is a pioneer work, and give it credit for being what the author claims for it, "A modest contribution to the knowledge on the subject."

(b) Civilization and Climate. (Huntington).<sup>19</sup>

Huntington discusses many phases of weather and climate in its relation to civilization and to the activities of mankind in general. Incidentally, the author collects such data concerning the influence of the weather on the quantity of work done by factory workers in various parts of the United States and Cuba, and gives his results. Among factory workers in New Haven, the lowest point of efficiency is in the last half of January. It rises slowly to June, drops slightly through July and August, rises quickly in September, and culminates around the first of December,

He gives several graphs of work done by factory workers in various parts of the United States, all of which are similar. Further south the culmination comes a little later in the season and varies from sometime in November in New Haven, to the middle of December in South Carolina and Florida. Southern workers also show a disposition to hold the high level till about the middle of January, while farther north they show a decrease in working capacity somewhat earlier.

(c) Effects in Weather on Ability to Learn. (Lehman)<sup>25</sup>

Lehman conducted a series of tests to discover the effects of weather on ability to learn rows of syllables by heart. The subjects were several university students and the tests lasted from October, 1905, to March of the following year. A device was used which allowed but one syllable to be visible at a time. One hundred thirty rows of 16 syllables each were prepared. Each syllable was presented for .75 seconds and the full rows were presented at intervals of three seconds. The subjects were scored on the number of repetitions necessary before being able to give a perfect reproduction of the row. The results appear in the following table:

Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May	Jun.
518	521	559	528	618	555	612	549	642	553

This shows a rise to a high level in January, a drop for February, a quick rise in March, and a culmination in May. From these data he concludes that the variations of memory agree much better than those of muscle strength with those of air pressure. The curve swings up and down during November and December, but shows a rise in January. In conclusion he says that memory is probably influenced in the same way as muscle strength by meteorological conditions.

(3) EFFECTS OF VARIATIONS IN SUNLIGHT.

Though the exact effects of sunlight on the human organism are unknown, much has been written about its stimu-

lating effects, and we have all felt its power. Dexter suggests that sunlight and clear days cause an excessive amount of "reserve energy" which must be worked off. In this way he accounts for the excesses of assaults, murders, and suicides on sunny days. In his study he also finds that there are fewer errors in banks on sunny days, indicating that sunny days are more favorable to mental work than cloudy days.

Lehman and Pedersen after a thorough and systematic investigation of the effects of sunlight on muscular ability come to the conclusion that next to temperature, the effects of light on muscle strength are more pronounced than any other one cause. They measured light strength with a Steenstrup Photometer and found that muscle strength begins to rise in January with light strength, and continues to grow with it until July when the good effects are overcome by the bad effects of excessive summer heat.

#### (4) EFFECTS OF CHANGES IN TEMPERATURE.

(1) Introduction. Perhaps the most important influence of all the varied weather conditions is that of temperature. The effects of extremes of heat and cold are well known. If our bodies are too long exposed to a low temperature without protection, the nervous system becomes paralyzed and death ensues. If our body is exposed to extreme heat for too long a time, discomfort, sleepiness, and finally a heat stroke results.

(2) Body Temperature. In any study of heat effects on human life, however, the body temperature is perhaps the most important factor. In spite of many external changes, this remains fairly constant. The temperature of the air surrounding the body under our clothing is about  $90^{\circ}$ . We keep this fairly constant by wearing a greater or less amount of clothing. The average body temperature remains constant at about  $98.6^{\circ}$  F. or  $36^{\circ}$  Cent. This varies with individuals, and with the same individual on different days.

(3) Benedict and Carpenter.<sup>3</sup> These investigators found a minimum body temperature from 3 to 5 a. m., a marked increase at about 7 a. m., a slow, steady rise through the evening to the minimum at from 3 to 5 a. m. They also found variations in the body temperature of one subject to be  $2.29^{\circ}$  F. on the first day, and  $1.67^{\circ}$  F. on the second day.

(4) New York Commission. This commission found that the body temperature of subjects living at home at 8 a. m., was high if the preceeding night had been warm, and low if the preceeding night had been cool. The variation was about  $1^{\circ}$  F. for  $20^{\circ}$  F. of atmospheric temperature.

(5) Burnham.<sup>5</sup> Burnham says that with an increase in the external temperature there is likely to be a rise in the bodily temperature, and this is accompanied by an increase in metabolism. Up to a certain optimum, this increases the activity and the efficiency of the organism, beyond that, the increase in metabolism caused by increase in temperature brings about a condition where the oxidation and elimination processes are not sufficient to carry off the waste products, with the necessary rapidity, toxic products accumulate, and thus fatigue comes quickly. Recent studies indicate that the cause of heat stroke and sun stroke is an abnormal change in metabolism.

(7) Dexter.<sup>7</sup> Dexter reports that in New York City, when school room temperature was below  $68^{\circ}$  F., the misdeemeanors were below normal, from  $69^{\circ}$  to  $73^{\circ}$  F. they were about normal, while in a temperature of  $79^{\circ}$  F. they were below normal.

(8) Hines.<sup>18</sup> Supt. Hines, of Crawfordsville, Ind. reports the following in regard to the effects of various classroom temperatures:

80° F.,	Class restless and dull.	70° F.,	Excellent work.
74° F.,	Not so dull as above.	68° F.,	Best work today.
72° F.,	Restless.	66° F.,	Splendid work.

65° F., Class happy and full 60° F., Too cold for good  
of work. work.

(a) Influence of Temperature on Rapidity of Addition. (L. and P.)<sup>25</sup>

From May, 1906, to February, 1907, both Lehman and Pedersen took daily tests in rapid addition each morning either before or after the dynamometric measurements, there being seven columns of 50 one place numbers in each test. The results were then compared with variations in air pressure, light strength, and temperature. The conclusions are as follows: "Up to the present we have not been able to show any dependence of rapidity of addition on light strength or air pressure. As soon as the small variations are effaced by taking the averages for each five days, the remaining variations show themselves almost entirely independent on temperature." The results are shown graphically, and indicate that when temperature sinks, rapidity of addition rises, and vice versa, the variation in rapidity of addition beginning only after temperature variation has continued a short time.

(5) EFFECTS OF VARIATIONS IN HUMIDITY.

The humidity of the atmosphere is very closely related to temperature in its effects on human life. It especially affects the body in its efforts to maintain a constant temperature. One of the chief means for keeping the temperature of the body from climbing too high is perspiration. Whether this takes place at the proper rate depends as much on the humidity as on the temperature. Though the disagreeable effects of humidity on bodily comfort are well known, they have not been investigated apart from temperature to any extent.

The New York Commission found that bodily temperature was lowered by confinement in an atmosphere of 68° F.,

with 50 per cent. relative humidity, that it was raised in an atmosphere of  $75^{\circ}$  F. with the same humidity, and raised still more in an atmosphere of  $86^{\circ}$  F. with 80 per cent. humidity. The same commission found the average pulse rate at  $86^{\circ}$  F. with 80 per cent. humidity to be 74, and at  $68^{\circ}$  F. with 50 per cent. humidity to be 66. The report also says, "Eastman and I have seen the pulse rate increased by 39, from 67 to 106, as the temperature of the surrounding air rose from  $74^{\circ}$  to  $110^{\circ}$  F., and the humidity rose from 50 to 90 per cent. (Page 185).

All these facts would indicate that excessive humidity not only causes extreme physical discomfort, but that it has a more or less distinct and direct influence on mental and physical efficiency.

Dexter's <sup>7</sup> findings seem to agree with the above. He found that a low humidity caused an excess of occurrence in nearly all classes of data studied, and vice versa.

Kuhnes<sup>21</sup> found that among 8 students, the best work was done when the relative humidity was from 75 to 85 per cent., but when the relative humidity fell below 50 per cent. there was a marked drop in efficiency.

Huntington<sup>19</sup> found that in winter, the dampest days are unmistakably the times of greatest efficiency. ("We may shiver when the air is raw, but we work well." The reason is two-fold. In general the temperature rises in times of excessive humidity and this of itself is favorable. In spring and fall when the temperature ranges from freezing to  $70^{\circ}$  F. with an average of about  $50^{\circ}$  F. the best work is done with a relative humidity of about 75 per cent. In other words, neither dry nor wet days are the best. The summer curve is a complex one. It rises first to a maximum at 60 or 65 per cent., then falls, and once more rises to a higher maximum. The first maximum is due to humidity, the second to temperature. A hot, damp day is debilitating. The majority of the dampest days in summer are compara-

tively cool for they accompany storms. The coolness counterbalances the humidity and efficiency increases. Hence, we conclude that with an average temperature of 60° F. to 70° F., a relative humidity of about 60 per cent. is desirable.”

His curves also show a diminution of work in dry weather. This evidently has a bearing on the low level of the curve of energy in winter. At that season the air in the house is only 16 to 20 per cent. relative humidity, and it should be 60 to 65 per cent. On cold days the percentage is still lower. It dries up the mucious membranes and is favorable to colds, besides producing deaths in February and March.

#### 6. EFFECTS OF BAROMETRIC CHANGES.

There is much difference of opinion as to the effects of barometric changes. The general idea seems to be that of Dexter, who says that the general effect of high altitudes is undoubtedly an invigorating one. His investigation shows that with the sole exception of his study of Errors by Bank Clerks, a low barometer is favorable, while a pressure above the normal is unfavorable.

Lehman and Pedersen on the contrary, found that muscle strength is so influenced by air pressure in the spring, that it rises and falls with the same, that it is independent of air pressure in the fall up to the end of November, that from December to March the variations agree more and more closely, and from April to June they seem to agree very closely. After June there seems to be no relation till December. A change from a sea level to a height where air pressure is 99 mm. lower, has no influence on muscle strength, neither is muscle strength influenced by a continued stay at such a height. A return to the sea level, however, causes a more or less noticeable rise in muscle strength, according to the temperature, but it lasts only a short time. These effects are shown in the following table, where the averages of the positive and negative deviations of muscle strength of

Lehman on two different years, Miss J. and the Boys' class are compared with the barometric readings.

Barometric Readings	L 1905	L 1906	Miss J.	Boys
Above 763	+0.09	+0.28	+0.47	+0.15
Below 762	-0.03	-0.17	-0.44	-0.49

Kuhnes found that of 8 test persons, 6 were at their best when the barometer was .10 above normal, and one each at .10 and .20 below normal, though in each of these cases, the second best record was at .10 above normal also. It would seem, therefore, that a barometer slightly above normal is beneficial to muscle strength.

#### 7. SUMMARY OF PROBLEMS AND RESULTS IN WEATHER EFFECTS.

There seems to be very little doubt that both mental and physical energy is influenced by the character of the climate in general, wind, sunshine, temperature, humidity, and air pressure, though the exact effects are still somewhat uncertain.

(1) Precipitation. Some authors find that precipitation has little or no effect. This is the view of Dexter. Huntington finds that physical efficiency is high at the close of a storm.

(2) Winds. Dexter finds that calm weather results in decrease in vitality, while moderate winds and high winds cause vitality to increase to a certain point. Excessive winds cause a decrease in vitality.

(3) Character of the Day. The effects of various kinds of days on mental and physical abilities seems to be contrary to general opinion. Dexter suggests in one place that sunlight and clear days cause an excessive amount of reserve energy, and must be worked off. In another he finds that for all the data studied, except deaths, sickness, and errors in banks, cloudy days are more favorable than fair days. He was surprised to find more suicides on cloudy days than

on days with precipitation, and more on fair days than on either of the others.

Lehman and Pedersen found that next to temperature the effects of light were more pronounced than any other cause. Huntington found that people are least efficient in work on clear days, moderately efficient on cloudy and partly cloudy days, and most efficient at the end of a storm. He also finds that ability to work on the first clear day is very poor, the second and third clear days are better, the first cloudy days when storms start are medium, and from the second to the last of a series of stormy days, when storms break, is very high.

(4) Temperature. Changes of temperature are perhaps the most important of all atmospheric influences, and operate directly by causing changes in the body temperature. The body temperature must be kept fairly constant at about  $98.6^{\circ}$  F. This has been found to vary slightly with different individuals and in the same individual on different days. Benedict and Carpenter, and another investigator, Polio-manti,<sup>33</sup> find a daily rhythm of body temperature, starting from the lowest point between 3 and 5 a. m., showing a sharp rise at 7 a. m. and a slow, steady rise through the day, culminating between 3 and 6 p. m., then falling slowly to the minimum between 3 and 5 a. m.

Lehman and Pedersen find that when the temperature sinks rapidity of addition rises, and vice versa, the variation of rapidity of addition beginning only after the temperature variation has continued a short time. They also suggest that each person has a temperature optimum differing for mental and for physical work, and that the abilities increase as the temperature nears the optimum either from above or below.

Huntington located the optimum for physical work between  $59^{\circ}$  and  $65^{\circ}$  F., while Lehman and Pedersen locate

theirs at  $54^{\circ}$  and  $59^{\circ}$  F, respectively. Students at Annapolis worked best when the outside air was  $40^{\circ}$  F.

Burnham<sup>5</sup> says, there is apparently an optimum temperature for all forms of activity, fixing it in man at an outdoor temperature of  $60^{\circ}$  F. for physical activity, and at  $40^{\circ}$  F. for mental activity. Concerning ventilation of school rooms, Burnham states that the primary purpose of ventilation is to maintain an optimum temperature, and concludes that the optimum temperature for a school room seems to be about  $68^{\circ}$  F. with a relative humidity of about 50 per cent.

(5) Humidity. Humidity especially affects the body in its efforts to maintain an optimum temperature by its influences over the amount of perspiration. Huntington finds that in winter, the dampest days are best; in spring and fall when the average temperature is about  $50^{\circ}$  F. we work best with a relative humidity of about 75 per cent.; and in dry weather there is a diminution in the amount of work done.

Dexter found that a low humidity caused an excess of occurrence of nearly all classes of data studied, and vice versa. Kuhnes found that the best work was done when the relative humidity was from 75 to 85 per cent.; but when the relative humidity fell below 50 per cent. there was a marked drop in physical efficiency.

(6) Barometer. The general opinion concerning the influence of barometric changes seems to be that of Dexter, that a low barometer and high altitudes are favorable to mental and physical activities. On the contrary, Kuhnes found that a barometric pressure of about .10 above normal, with slight individual differences, seemed to be the most favorable, and Lehman and Pedersen also found an increased efficiency with high barometric pressure. They also found that a change from sea level to higher land has no influence, but that on a return to the sea level, a more or less noticeable rise occurs which varies with the temperature conditions. They claim that in the spring, muscle strength rises and falls

with the barometer, that they separate in July, and are independent till December, when they begin to agree more and more closely, coming into very close agreement in March.

#### 8. WEATHER EFFECTS IN MY ORIGINAL EXPERIMENTAL INVESTIGATION.

(1) Character of the Day. In order to study the effects of the general character of the day I have used the U. S. Government Weather Reports and arranged the days of the month under the three heads of clear, partly cloudy, and cloudy in the accompanying tables.

##### AVERAGES OF RIGHT HAND GRIPS

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May
Clear Days	45.8	49.8	52.5	53.8	54.2	54.6	55.9	58.8
Ptly. Cldy.	46.2	50.5	54.9	53.8	54.4	55	56.9	59.6
Cloudy	46.8	49.3	52.8	54.7	54	54.6	56.1	58

##### AVERAGES OF LEFT HAND GRIPS

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May
Clear Days	42.3	46.8	50.2	50.5	50.9	52.6	53.6	55.4
Ptly. Cldy.	43.1	47.2	53.6	52.4	51.3	53.2	55.5	57.3
Cloudy	42.6	46.2	49.4	51.8	50.5	52.5	54.2	55.8

These tables show that partly cloudy days are the most favorable for muscle strength, that cloudy days are next, and that clear days are least favorable. In the three months, November, February, and May, it appears that cloudy days are slightly less favorable than clear days. An examination of the original data, however, shows that in November all the cloudy days were in the first half of the month, and as there was a large increase in November the seeming advantage of the clear days disappear. In May also, the only two days called cloudy, come in the first week of May so that the advantage of the clear days disappears here as well. In February the low record for cloudy days is caused by low averages on two days, February 7 and 13, in the right hand. In each case the low daily average is due to a remarkably low mark by two boys of the group. During the months of

January, February, and March, it was not unusual for a boy to drop from 3 to 5 Kg. for a day or for a week, and as suddenly recover his efficiency. The low marks above are such special cases. We are, therefore, justified in the conclusion that partly cloudy days are the most favorable to muscle strength, cloudy days next, and clear days least favorable.

In the table for the Mental Tests, the advantage of the cloudy and partly cloudy over clear days is not so marked.

#### MEMORY TEST AVERAGES

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	May
Clear Days	9.4	10.4	10.8	11.1	10	10.6	11.3	11.2
Ptly. Cldy.	10.2	10.4	11.1	10	10.2	10.2	10.9	11
Cloudy Days	9.3	10.7	10.9	10.6	10.2	10.6	11.4	11.5

Here we see a small advantage for cloudy days in every month except January, and as in the muscle tests we find January, February, and March to be a time of unusual results. The unusually high average for clear days in January is due to especially high scores on January 9, where two boys scored 15, and two 14; and on January 8, where one boy got 15, and three boys 13 points each.

From the above data, therefore, we are warranted in concluding that cloudy and partly cloudy days are rarely a disadvantage, and that they may be positively advantageous to both physical and mental activities.

#### (2) Temperature, Humidity, and Light Strength.

In the tables where the weekly averages of the grip strength and memory records are compared with the weather variations, we find some variations in efficiency seem to be due to changes in temperature, humidity, and light strength, or to various combinations of them. In general, the results for muscle strength show a rising tendency in the fall as the temperature decreases, a period of arrest, while the temperature is low, and a tendency to increase with increasing light strength from the first of March, which is aided by rising temperature from the first of April to the end of the tests in

June. These are the same variations which Lehman and Pedersen found in their study. A question might be raised as to why light strength should not have influenced muscle strength earlier in the year. A glance at the tables, however, shows the reason why this is delayed. From the first of January to the last of February, we find only 11 clear days, and a relative humidity of from 75 to 100 per cent. on all but four of the days during that time. This would indicate a long season of cold, damp weather, with a soft, and muddy soil, a time when the boys would not take much outdoor exercise, and when their vitality would probably be very low. That this is true is also shown by the fact that in this season of the year we find the only time when the average strength on clear days shows a superiority over that on cloudy days. It would further seem that cold weather with excessive humidity is unfavorable for muscle strength on account of its direct effects on the temperature of the human body.

The data also show that while a moderately high humidity is favorable for temperatures of from 40° to 80° F., it is unfavorable when the temperature is below that point. Several instances may also be found in the records where a drop in the temperature accompanied by a rise in the humidity, caused a decrease in muscle strength, and an increase in memory ability.

From a search among the individual records, we find that while the whole group did not lose in physical and mental efficiency at the same time, they all experienced a more or less pronounced slump sometime between the middle of December and the first of April. Two of the ten began to slump in December, the other eight beginning in January, and they all last from three to ten weeks. In the A. division, for the grips, five begin to slump in December, fourteen in January, and three in February.

It is very evident, therefore, that there are some causes at work which cause a decrease in physical efficiency during

the months of December, January, and February, and two months of cold, cloudy, damp weather with low temperatures and high humidity, are undoubtedly among the causes.

## CHAPTER VII.

# CRITICAL REVIEW OF EXPERIMENTAL METHODS IN INVESTIGATING PERIODICITY

(1) INTRODUCTION. We have seen that both mental and physical activities are far from being constant, and that there are many factors which seem to have a causal relation to them. While, as a whole, both the mental and physical tests show many irregularities, there are many rhythmic periods shown in the results. The causal factors which produce these variations are sometimes very obscure. In addition, many other factors appear in an investigation of this kind which tend to produce variations in the data, such as materials, procedure, methods of checking, and treatment of results.

There are often so many peculiarities in the records for a group, that it is frequently difficult to account for them in any other way except individual differences. The following records for the week from March 13 to 17, all taken at 2 p. m., with little difference externally in temperature, or humidity (high on Friday), are typical of the results and show the difficulties in discovering causes by comparisons of variations.

Subject	March 13				March 14				March 15				March 16				March 17			
Ba	4	3	3	10	4	3	5	12	3	4	5	12	4	5	6	15	2	4	3	9
Be	4	5	6	15	4	4	3	11	2	2	4	8	4	3	5	12	4	3	1	8
Ch	4	1	5	10	4	5	4	13	4	4	5	13	3	4	4	11	4	5	4	13
Cu	3	5	3	11	4	5	4	13	4	2	3	9	4	4	1	9	4	3	3	10
Fr	4	3	3	10	4	4	5	13	4	2	1	7	4	3	4	11	4	3	2	9
Ke	4	5	3	12	3	1	2	6	4	2	5	11	4	1	0	5	2	3	3	8
La	4	3	4	11	4	1	5	10	3	1	2	6	4	4	4	12	1	4	1	6
Me	4	5	3	12	4	5	2	11	4	3	4	11	4	3	3	10	4	4	4	12
Mi	4	5	4	13	4	3	3	10	4	4	5	13	4	5	3	12	2	5	1	8
Ru	4	1	1	6	4	3	2	9	2	3	4	9	4	2	4	10	3	3	2	8

From the above results it would seem that unless we find a variation which is quite general, the cause is very difficult to discover except by statistical and graphic methods, and thus we are never sure whether similar variations show casual effects or not. No doubt the excessive humidity on March 17th contributed to the lowness of the mark, but the fact that it was on Friday, and St. Patrick's Day, may also have influenced the results.

## (2) DETAILED DISCUSSIONS OF SCIENTIFIC METHODS.

In any experimental investigation concerning periodicity as shown in mental and physical tests, the chief things to be considered are:

I—Adaptability of means to the end. This is one of the first requisites. Any neglect here is sure to prove a prolific source of error. As a test of physical energy, the dynamometric tests seem to be one of the best as well as one of the easiest to make. The instrument used, the Smedley Dynamometer, is also admirably adapted to the use for which it is designed. Its light weight, as well as its adjustability make it an ideal instrument.

As to the reliability of the mental tests, there is a great variety of opinion. Many sorts of tests have been devised, and after a careful study of the field, I have come to believe that numbers and nonsense syllables make the best materials for immediate memory reproduction. While the material may be criticised on the ground of conflicting associations, a conscious effort was made to avoid such associations in making up the materials. In addition to this, the numbers used are so commonly associated with their spoken names, that this association would seem to be dominant. Because of the limited time, and the ease of making them, tests for the immediate memory of a series of two place numbers were chosen as the material to be used in the tests.

Primary memory tests involve both attention and immediate memory, so that the presentation of the material is important. Perhaps the presentation of the materials was such as to appeal more strongly to some types of minds than to others, but as the variations and not the actual score was to be used, this defect was largely overcome by a uniform presentation of the materials. At best, mental abilities are very complex, and the validity of the results depends more on the uniformity of the materials, methods, and procedure, than on any other factors, in making the tests. Immediate memory is so universally depended upon in everyday life, that its importance for the mental life is second to none. We conclude, therefore, that though the tests may be criticised, the same criticism may be applied to almost any sort of reliable mental tests, and that the tests used are about as reliable as any tests yet devised.

2—Uniformity of Materials. While some of the tests may have been slightly more difficult than others, the differences were not great. This would perhaps account for occasional differences, of the whole group on different days, and for differences in the memory for the series of fours, fives, and sixes for the same day, but it could not account for such differences in the weekly record here given, where one boy's record is 4, 5, 0, and another's is 3, 0, 6, etc., on the same day. As differences of this sort are much more common, we must conclude that differences in the materials caused little if any of the variations in the results.

3—Similarity of the Materials. There may perhaps have been some associations formed in the first series of four numbers which persisted until the second or third series, but a careful search in the original records shows only a few errors which could possibly be due to such associations. The elimination of all such associations is very difficult. Both Lobsien's and Gates' materials also suffered from the same

causes. While this defect might account for a few minor errors, the effects should not be over-estimated.

4—Time of the Year. Though the results of this investigation seem to show a course of seasonal periodicity, it is not pronounced. It is evident, however, from almost all studies, that there is a lowering of abilities beginning sometime between December and February, and that the periods from October to December, and from March to June, are more favorable than from December to March for mental abilities. This agrees practically with the low point in the muscle tests, and shows there is some sort of relation between them. In this test, also, the memory results do not go contrary to those for muscle strength as do Schuyten's and Lobsien's, but keep their level all through to the end of May. It may be true that the time of the year is not a real cause, but that the real causes are changes in temperature, light strength, air pressure, humidity, etc., but they are so closely related that for all ordinary purposes we may relate the variations in the results to the seasons of the year.

5—Time of the Week. Some investigators have found variations which seem to correspond to the time of the week, though the results of this investigation do not seem to be much affected by it. The effects indicated seem to be due to other causes.

6—Hour of the Day. There seems to be no doubt about a diurnal course of efficiency, and it must always be taken into account by those who conduct investigations concerning mental and physical abilities. Its effects are quite apparent in the records shown during the first three months by the B. division. Early hours are never so favorable as later ones, and the maximum is usually found in the afternoon.

7—Temperature. Quick temperature changes, unseasonable temperature, and extremes in either direction seem to cause a drop in abilities, while slight changes seem to be beneficial. There are grounds for believing that each per-

son is affected in a unique way by variations in temperature, and that there is an individually varying optimum temperature for each person. The bodily temperature is very closely related to outside temperature and is a resultant of outside temperature, humidity, exercise, ventilation, food, clothing, etc.

In these tests temperature played a prominent part. All the tests were made in a large, light, airy room, with a thermostat set at  $67^{\circ}$  F., which regulated the temperature of the room. The heating and ventilating was controlled and regulated by a combination of the plenum and exhaust systems, and three kinds of air—hot air, outside air, and air passed over steam jets to regulate the humidity. The temperature conditions in these tests were therefore fairly constant, and kept around  $67^{\circ}$  F.

8—Humidity. An excess of moisture or a lack of moisture in the air seems to be the cause of low efficiency in both mental and physical tests, though in this as well as in temperature, there seems to be an individually varying optimum. It must therefore be taken into account in any study on periodicity.

9—Air Pressure. A change in air pressure does not seem to produce much effect on either mental or physical activities unless it is continued for a long time.

10—Fatigue. No doubt fatigue is an efficient cause in the variations of both mental and physical abilities. In this investigation, however, I have tried to eliminate the influence of fatigue variations so far as possible, by giving short tests always at the same hour of the day. It is of course to be doubted that each individual was equally fatigued at the same hour each school day, but with only one record per day, we have no basis for discovering its influence.

It appears from other studies that when the body temperature increases above the optimum, the waste products are not

eliminated fast enough, and that they act as poisons, diminishing all activity and that fatigue then comes on rapidly. From the study of Gates, we see also that one's own ideas as to his abilities are not always reliable. The influence of fatigue, however, cannot be excluded from these results, but it must remain an unanalyzed factor in the diurnal course of efficiency.

11—Daily Habits. Of course the ability of an individual may be influenced by many daily habits, such as the time of rising, time of eating, character and quantity of the food, clothing, general habits of work, etc., but in such a study as this, the effects of such influences are very difficult to discover.

12—Practice Effects. In the physical tests, with growing youths for subjects, we see that the combination of growth and practice affects the results considerably. In this investigation, those who were tested five times weekly gained about twice as much at the same age, as those tested but once weekly. The mental tests, however, do not show these effects so plainly. It is probable that they are one of the chief causes for the fact that both muscle and mental abilities, when tested for any considerable time, show rising tendencies through the greater part of that time.

13—Exercise. While this is closely related to practice effects on the one hand, and fatigue on the other, exercise has an effect all its own. It is especially shown that physical tests taken before and after exercise show an increase in efficiency, and that rest after continuous work, either mental or physical, increases both mental and physical efficiency.

14—Other Individual Differences. There are many other factors involved in a study of mental and physical periodicity, such as age, sex, health, working habits, rest periods, sleep, endurance, pulse rate, blood pressure, etc., which may or may not influence the results from physical and mental tests. In these tests, where we must limit our study to mass results, it

is well to recognize possible causes even though we cannot point out their influence in any particular case.

15—Checking the Results. In any statistical study, the checking of the results is very important. When physical tests are given with a dynamometer, the results are at once expressed in a measurable quantity. It is otherwise with the results from the mental tests. In this instance, I decided to give a single point for each number correctly given in the proper order, one-half a point for a correct number in the wrong order, and one-half a point for each correct digit in the right place and order.

The next question was which number series to count. The four series was good but too short. The five series was better, and the four series served as a sort of preparation for the five series. The six series was rather too long, but it gave an opportunity for those with high ability to use all of it. After considering the merits of each of the three series, I decided to use all of them, for though they were quite different, they were to be used for purposes of comparison. But I have given the weekly averages for each of the number series in the tables, and I have used them in making comparisons with the weather. The results from all three prove to be very similar so that the use of the three series again justifies itself.

16—Uniformity of procedure. It is necessary to reduce procedure to a basis of strict uniformity, for variations in procedure may cause many accidental errors. Every investigator needs to have preliminary trials or tests, and work out the details of procedure thoroughly before starting the main tests upon which the results are to be based. The tests should always be taken or made by the same person, or serious differences may destroy the validity of the results.

17—Statistical treatment. In taking the physical abilities of a group, both the median and the average are

commonly used. The median may be valuable in testing a homogeneous group where the distribution of results is important, but in a group like the ones in this study, the variations are more important than the distribution. I have, therefore, used the averages. In the mental tests, the median is perhaps more important on account of the slight difference in ages, or in the study of a single test person. The median is given in some of the mental tables, but for the sake of comparisons, the main thing is uniformity of treatment, therefore, I have used the averages throughout in making the comparisons.

18—Tabular presentation. The tabular presentation should be quite complete, showing as much of the detail of the data as possible. Tables should organize the data so that certain tendencies will appear plainly, and they should be used to illustrate the facts claimed to be discovered or proven by the investigation. The chief care, however, should be to give the complete data, so that others may examine in detail and discover whether the conclusions drawn are warranted by the data.

19—Correlation of results. While a correlation expresses a certain mathematical relationship between two sets of data, from a great amount of work we get only a single mathematical expression which entirely neglects the details of the study. The value from such relationships is purely statistical, and the presence of a high correlation proves nothing.

20—Verifying Tests. It is always valuable when possible to conduct a series of verifying tests, in order to discover whether the results show general instead of special tendencies, and to prove the results of the real tests. In this investigation, I can only use the records from the A. Division for that purpose. They show the same general tendencies as the results from the B. Division and tend to add to the value of the results.

(3) **VALIDITY OF THE RESULTS.** The validity of the results depends almost entirely on the choice of means and materials, and on the degree of control exercised by the experimenter over the means, methods and procedure. In this case, the means were a typical group of high school boys of various ages. The method in the physical tests was one which has been used many times for similar purposes, and extreme care was used by the experimenter to keep the procedure uniform. The results from the physical tests are of unusual validity, and should be so considered.

The means used in the mental tests, though open to criticism in minor points, are perhaps as well adapted to the purpose as any which had been devised up to the time when this experiment was made. It was necessary to have a series of mental tests that would not consume too much of the student's time, and one that would be of about uniform difficulty. Nonsense syllables were considered, but the task of making a sufficient number of tests, enough to last for a whole school year, in a short time, was too great, so numbers were chosen. By using two place numbers, a series of three hundred mental tests was made from materials which are so common that associations between the numbers were lost from one day to another, and in this way each series was entirely new when presented. Then again, the results from the memory tests are not expected to set standards of mental ability, but to furnish data for comparisons. They can therefore be used for that purpose to good advantage, and for purposes of comparison, the results are perfectly valid.

## CHAPTER VIII.

### SUMMARY AND SUGGESTIONS

The following significant facts concerning periodicity seem to be indicated by the results of my investigation:

(1) There are three distinct periods in the physical strength of growing boys in the course of a school year, a period of growth from September to about the middle of December, a period of depression from January to March, and a period of renewed growth from March to June.

(2) There are also three more or less distinct periods in mental energy during the school year, the curve of which tends to resemble the curve for physical periodicity in the same group of subjects: first, a favorable period from September to the end of the year, an unfavorable period from January to March, and a second favorable period from March to May.

(3) The depression in mental abilities seems to appear somewhat after the depression in physical strength, is much less noticeable, and does not last so long.

(4) The period of depression in mental and physical abilities comes at the beginning of winter, and while it shows many individual variations, it occurs in all subjects studied and lasts from three to six weeks. Adults and boys of low vitality tend to show it early in December. Young and growing boys show it any time between the first of December, and the middle of January. In some subjects the effects are overcome by the middle of February, in others by March, but in special cases it sometimes lasts until May.

(5) Sunlight seems to affect mental and physical abilities favorably, the stronger its rays, the more its influence.

(6) Temperature has an individually varying optimum,

so that both the lowest and the highest temperatures have a depressing effect.

(7) The larger yearly periodic variations in mental and physical abilities are probably due in a large part to the combined influence of temperature and light strength.

(8) Other causal factors in periodicity are food, clothing, body temperature, humidity, air pressure, character of the day, fatigue, time of day, practice effects, previous mental and physical development, mental activity toward the activity tested, general bodily health, and various individual differences.

(9) Changes in temperature and humidity are at first seen in the changed body temperature. When long continued, they clearly affect both physical strength and mental abilities.

(10) There is nothing in the twenty-eight day periods of Malling-Hansen, or the twenty-three day periods of Fleiss-Svoboda.

(11) There is no distinct weekly periodicity as shown in the mental and physical tests. While Monday seems to be more variable than the other days of the week, in general, the changes which appear from day to day seem to be due to other causes than merely the time of the week.

(12) There is a distinct diurnal course of efficiency shown in both the mental and physical tests. Both increase quickly through the forenoon, each show a slight decrease around noon, and both come to a maximum in the afternoon. That for mental abilities culminates around 2 p. m., while that for physical abilities often comes later in the afternoon.

(13) Cloudy and partly cloudy days, if not too long continued, are usually more favorable to both muscle strength and mental efficiency, than clear days. Cold, cloudy weather with a high humidity, when continued through several days, is unfavorable to both mental and physical abilities.

(14) In general, the cyclonic movements of the air which precede a storm, seem to be favorable to muscle strength, while the anti-cyclonic air movements which follow, seem to have a depressing effect.

(15) The existence of an individual optimum in temperature, in air pressure, and in humidity, which is most favorable to mental and physical activities, is very important, and should be further investigated.

(16) Most of the investigations in this field are suffering from the effects of statistical treatment of the facts. Many times, more can be learned from the careful study of one subject than from the statistical treatment of the results from a large number of subjects.

(17) There is need of many careful experimental studies on the influence of various climatic conditions and atmospheric changes on individuals.

(18) There is need of many more investigations concerning both mental and physical periodicity where the conditions are carefully controlled.

## CHAPTER IX.

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